R White ad vivum delin: et Sculpsit

DIALLING,

PLAIN, CONCAVE, CONVEX, } { *PROJECTIVE, REFLECTIVE, REFRACTIVE.*

SHEWING,

How to make all ſuch *DIALS*, and to adorn them with all uſeful

FURNITURE

Relating to the

Courſe of the SUN;

PERFORMED

ARITHMETICALLY, GEOMETRICALLY, INSTRUMENTALLY and MECHANICALLY:

AND

Illuſtrated with SCULPTURES, Engraven in COPPER.

Compriſed in XIV. Diſtinct TRACTATES, the Contents whereof follow next after the *Preface* to the *Reader*.

The SECOND EDITION Corrected, and two *New Tractates* added.

Collected, Methodiſed, and Publiſhed,

By *WILLIAM LEYBOURN.*

LONDON:

Printed by *J. Matthews*, for *Awnſham* and *John Churchill* at the *Black Swan* in *Pater-Noſter-Row*, MDCC.

TO THE READER.

Many of the following *Miſcellanious Tractates* lying obſcurely and indigeſted by me ſeveral Years, at length, namely, *Anno* 1678. having ſome vacant time, I (amongſt other things) took thoſe Papers into my conſideration, and perfected ſuch of them as were incomplete; adding to that Store other things of the like nature: After which, communicating the ſame to ſeveral perſons Mathematically affected, and more particularly with this (laudable and uſeful) Part thereof, namely, *DIALLING:* I was often-times importuned to make the ſame Publick; the which I was the more inclinable to, for that not much of this *Variety* hath been hitherto Publiſhed in the Engliſh Tongue. But finding the Overtures of ſuch who deal in the Publiſhing of Books, to be in no meaſure ſufficient, either to ſatisfie me for the pains I had then taken therein, much leſs to bring it forth in its due Luſtre; I (at length) adventured to make an Eſſay towards the Publiſhing thereof by way of *Subſcription*, but finding that not to anſwer my expectation neither (there having been of late ſo many abuſes put upon Perſons, willing to promote ingenious undertakings) I fully reſolved to let it lie dormant, as (the more part of) it had done ſeveral years before. But at length, (partly by Subſcriptions, and a particular Encourager) it is arrived to this perfection; and an Extract of the Particulars herein contained, you ſhall find immediatly after this Preface.

And now give me leave to prevent the Calumnies of ſome (already) Detracters, and to take off the aſperſion of a Plagiary, to acquaint thee from whence all that is herein contained had its iſſue. Therefore.

1. The *Introduction*, and the Eight firſt *Chapters* of the firſt *Tractate*, as things common, (but neceſſary for all *Tyro*'s to be acquainted with) I paſs over, only take notice, that the Second, Fourth and Fifth *Chapters* thereof, which concerns

the *laying down*, *finding the Poles* and *Centers*, and *measuring* the *Sides* and *Angles* of *Spherical Triangles* upon a *Projection*; I know not where you will find any thing thereof, except in my *Geometrical Exercises*, the which *Precepts* there delivered I have here (and in a brief manner too) applied to *Dialling*.

2. For the remaining part of the first Tractate, the Examples are all (or most of them) the same as are Mr. *Wells* in his *Sciographia*, which I made choice of (indeed) to ease my self of Calculation; My intent (at first) being to have done the Work of the First *Tractate* by *Projection* only, and not by *Calculation*: But Mr. *Wells* his Book being out of Print, and not likely to be restored, I inserted his *Calculatory* way also; and the rather, that the young Practitioner may discover what Harmony there is between *Spherical Projection*, and *Trigonometrical Calculation*, and the reason thereof also.

3. The Second Tractate was, partly a Translation out of *Magnon*, by Mr. *Thomas Gibson*: And the Third is partly Mr. *Samuel Foster*'s.

4. As for the Fourth Tractate; it is an enlargement of the Appendix to *Stirrup*'s *Dialling*, written by me above 25 years since, and yet, in it, you will find several things, which I am sure, no other Book will afford you.

5. The Fifth Tractate is of the same kind with the Fourth, and teacheth how to perform the same things by a different Artifice.

6. The Sixth consisteth of *Tables* subservient to the inscription of *Furniture* into *Sun-dials*, some few whereof were only transcribed (though much enlarged, and otherwise disposed) out of *Kirkerus*; but the most of them, were (to my great pains) Calculated *de novo*, and the *Description*, *Construction* and *Uses of them* all, wholly by me added

7. The Seventh Tractate came to my hands in a Latine Manuscript of Mr. *Samuel Foster*'s, written with his own hand *in Anno* 1640. and was delivered to me (when the other Tractates were almost Printed) by a real honourer of the deceased Author, and my very worthy Friend *John Twisden*. *M. D. C. L.*

8. The Eighth Tractate is no other then the *Meridians* of a *Globe* set to any Latitude and difference of Longitude, and Meridians or *Hour-lines* drawn on the Concave Superficies of the same.

9. The Ninth Tractate is wholly Mr. *Samuel Foster*'s, and

some

ſome part thereof was Printed by me in his *Miſcellanies*, *Anno* 1659.

10. The Tenth Tractate alſo, is wholly his; and was (together with ſome part of the Ninth) tranſcribed from a Manuſcript of his, which he (for the excellency of many things contained therein) Entituled *GOLD*. And for thoſe Pieces which follow (as Supplement to) this Tenth Tractate, I need not declare, their reſpective Titles will here ſave me that Labour.

11. The Eleventh Tractate of *Refracted Dialling*, is Mr. *Foſter*'s alſo, and was formerly Printed in his forementioned *Miſcellanies*.

Laſtly) What is ſaid concerning the Dial ſet up in the King's Majeſtie's Privy Garden at *White-hall*, *Anno* 1669. is but an Extract of what the Maker thereof did write concerning the Explication and Uſe of the ſaid Body of Dials: I did here (together with the Figure thereof) inſert this Abſtract for the benefit of Students in this *Gnomonical Science*; thereby to whet their inventions, ſo as to put in practice what is taught in theſe Tractates, and from this Preſident to invent others of their own; which how to perform the enſuing Precepts will not be found deficient; If they be deemed Redun dant they will be found ſo to Talkers only, and Doers of thing, and to ſuch I ſay as much.

What is more added in this Edition, (beſides the Errors in the former Corrected) Are,

Firſt, A *Supplement* to the Firſt *Tractate*, ſhewing a general and eaſie way, to *Project Hour-lines* upon all ſorts of *Plains*, according to the Rules of *Stereographick Projection*.

Secondly, To the ſecond *Tractate* is added a third way of *Geometrical Dialling*, ſhewing how to inſcribe the *Stile*, *Subſtile*, and *Meridian-line*, in all *Plains*.

Thirdly, To the Ninth *Tractate*, I have added ſeveral ways, whereby to make *Dialls* upon *Plains*, upon which the direct Beams of the Sun can never ſhine (without *Reflection*) which ſhall ſhew the *Hour* of the *Day* by the *Sun*, and by the *Stars* in the Night Seaſon.

Fourthly, The Fourteenth *Tractate* is wholly added and treateth of the Five *Platonick* (or *Regular*) *Bodies* ſhewing the manner how they *Cut* them in *Stone* or *Wood*, as alſo of two *Polyhedron Bodies*; one called the *Hex-octahedron*, (or *Canted Cube*) the other *Hex-icoſahedron*; the one conſiſting of *Fourteen*, the

other of *Twenty ſiix Plains:* And how to furniſh them in the *Sun Dialls.*

Having given you this general account of the ſeveral Tractates, and from whence they have been deduced, I now refer you for farther ſatisfaction, to the following *Contents*; but principally to the *Book* it ſelf; in which, I hope, the ingenious Practitioner will find variety of Matter, both *Practical* and *Delightful*; And for as much, as the ſeveral *Mathematical Treatiſes* which I have already Publiſhed, have found ſo good acceptance in the World, I doubt not but *This* will receive the like entertainment, and be as kindly received as his *Fellows:* and upon that account I commend it to thee; Wiſhing thee both *Delight* in the *Reading*, and *Profit* in the *Practiſing* of what is herein contained: And ſo, for this time, I bid thee Farewel; Reſting,

Thy well wiſhing Mathematical

August 15. 1681.

Friend,

William Leybourn.

THE

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A SUPPLEMENT.

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The Use of the *Line of Proportion*, made Easy, and by it to measure *Timber*, *Stone*, *Board*, *Glass*, *Pavement*, *Hangings*, *Wainscote*, &c. 12o.

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He hath now Preparing, and almost ready for the *Press*, These *Pieces* following, *viz.*

A *TRIGONOMETRIE*, *Plain* and *Spherical*; all Geometrically demonstrated.

A Treatise *GEOMETRICAL*, of *Astronomie* and *Geography*, wholly designed for *Navigation*; wherein that Art will be rendred far more easy than hitherto it hath been usually *Taught* or *Practised*.

URANIA PRACTICA Rediviva.

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THE Place of the *Author*'s Residence is about Ten miles from *London* Westward, at a Place called *Southal*, in the Road between *Acton* and *Uxbridge*, and three miles from *Brentford*: Where he intends to *Read* the *Mathematicks*, and Instruct young Gentlemen and others: And to Board upon reasonable Terms, all such as shall be pleased to make a more close Application to those Studies: Where such Boarders, and others, (during their time of Residence with him) shall have the Use of all *Books*, *Maps*, *Globes*, and other *Mathematical Instruments*, as are necessary for their *Instruction*, till they provide themselves of such as they shall have occasion for afterwards.

You may hear of him, and have an Account of his Terms, and manner of Proceedings: *By*

Mr. *Robert Morden*, at the Sign of the *Atlas* in *Cornhil*, near the *Royal Exchange*, *Globe-maker*.

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Ar

Arts and Sciences Mathematical *Profeſſed and Taught by the* AUTHOR.

Arithmetick,
- In Whole Numbers, and Fractions.
- In Decimals, and by Logarithms.
- Inſtrumentally, by Decimal Scales, Napiers Bones: And to extract the Square and Cube Roots by Inſpection.

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- The Principles thereof with the
  - Practice, and
  - Demonſtration.

Aſtronomie:
- Theorical and Practical.
- The Deſcription of the Circles of the Sphere.
- The Uſe of the Globes,
  - Celeſtial, and
  - Terreſtrial.
- To project the Sphere *in Plano* upon any Circle,
  - Right, or
  - Oblique.

And upon theſe Foundations, the following Superſtructures.

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- *Longimetria*, or the Menſuration of
  - Heights, Depths, Diſtances, as of
    - Trees, Towers, *&c.*
    - Mines, Wells, Deſcents, *&c.*
    - Churches, Towers, *&c.*
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  - Board, Glaſs, Pavement, Tiling, *&c.*
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- Or, the Menſuration of Triangles, both
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  - Spherical.
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  - *Mercator's* Chart.
  - The Arch of a great Circle.

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- *Arithmetically*, by the Tables of
  - Sines.
  - Tangents.
  - Logarithms.
- *Geometrically*, by
  - Scale, and
  - Compaſſes.
- *Inſtrumentally*, by the Sector, Quadrants, Scales, and other Inſtruments accommodated with Lines for that purpoſe.

ALSO

If any would have their Land or Building Surveyed, or Meaſured, and a Plot thereof made; or any Sun-Dial, or Dials about their Houſe or Garden (of what kind ſoever, Fixed or Moveable) he will prepare or make for them ſuch as ſhall be deſired.

A NECESSARY

INTRODUCTION,

Consisting of

DEFINITIONS and *PROBLEMS*,

Geometrical and Astronomical:

For the more easie Apprehending, and ready Performing of the several Matters and Things contained in the following *TRACTATES*.

PROBLEM I.

From any Point *in a* Right Line *given, to erect another* Right Line, *which shall be* Perpendicular *to the* Right Line *given.*

Definition 1.] A Point *is that which hath no Part; and is the least imaginary Thing; as this* Point *or* Prick *noted with* [Z •]

Definition 2.] *A* Right Line *is a Line drawn equally between two given* Points, *and is the shortest distance between them, as is this* Line X Y, *which is the shortest distance between the two* Points X *and* Y.

[X —— Y]

Definition 3.] *A* Right Line *is said to be* Perpendicular *to another* Right Line, *when it maketh the* Angles *on either side of the erected Line equal, that is, so that the* erected Line *inclines not, either to the* Right-hand, *or to the* Left; *but standeth upright upon the* Line *from which it is erected: As in* [Figure I.] *The* Right Line A B, *is said to be* Perpendicular *to the* Right Line C D, *upon which it is erected, for that it inclineth neither to the* Right *or* Left-hand; *and because the* Angles *on either Side thereof are equal; namely, The* Angle A B C, *on the one side, equal to the* Angle A B D, *on the other side; either of which* Angles *are* Right Angles, *and the* Right Line A B, *so standing, is* Perpendicular *to the* Right Line C D, *upon which it is erected.*

Practice.] LET the Right Line given be C D, and let it be required to erect another Right Line, which shall be Perpendicular thereunto, from the Point B. *Figure* I.

Open your Compasses to any convenient small distance, and setting one foot in the Point B, with the other make the two small Marks E and

F, on either ſide equi-diſtant from the given Point B.——This done, Open the Compaſſes again to any convenient diſtance, (greater than the former) and ſetting one foot in the Point E, with the other deſcribe the obſcure Arch G G, (over the given point B, as near as you can gueſs)——Again, (the Compaſſes being ſtill open at the ſame diſtance) Set one foot in the point F, and with the other deſcribe another obſcure Arch H H, croſſing the former in the point A: So is A, a point found, through which, if you draw a Right Line from the given point B, that Right Line A B, ſhall be *Perpendicular* to the given Right Line C D, and from the point B, which was required to be done: And the Angle ABD, on the one ſide thereof, is equal to the Angle A B C, on the other ſide; and both of them are Right (or Square) Angles.

Note, An Angle is always ſignified by Three Letters, as a Point is by One: The middlemoſt of which Three repreſenteth the Angular point, as in this Caſe the Letter B——B, being the Angular point, and the Lines A B, and B C the Sides, containing the Angle B.

PROBL. II.

How to erect a Perpendicular, when the given Point is in (or near) the end of the given Right Line.

Practice.] THere are ſeveral ways to effect this; of which I will here ſhew you only Two, as being the beſt.

Figure II. Let A B be a Line given, and from the point A, towards the end thereof, let it be required to erect the Perpendicular A C.—Firſt, Open the Compaſſes to any ſmall diſtance, and ſetting one foot in the given point A, with the the other deſcribe an Arch (or part) of a Circle F E D;—And (keeping the Compaſſes ſtill at the ſame diſtance) ſet one foot in D, and make a mark in the Arch at E, and ſetting one foot in E, with the other deſcribe another Arch of a Circle A F G, croſſing the firſt Arch in F.—Again, Set one foot in F, and with the other deſcribe the ſmall Arch H H, croſſing the former in the point C, through which point C, draw a Line from the given point A, and that Line ſhall be Perpendicular to the given Line A B, and drawn from the point A, as was required.

A Second Way.

Let B (the extreme end of the given Line) be the point given.——Open the Compaſſes to any convenient diſtance, and ſetting one foot in B, pitch down the other foot at adventure in the point K; ſo one foot reſting in K, turn the other about till it croſs the given Line A B in L, and draw the Right Line L K at length, and ſet the ſame diſtance K L, (at which the Compaſſes already ſtand) from K to M; ſo a Line drawn from B through M, ſhall be Perpendicular to A B, and from the given point B, as was required.

PROBL. III.

From a Point *above, to let a* Perpendicular *fall upon a Right Line under it.*

IN this there are two Cafes. — *First*, When the given point above, is over (or near) the *Middle* of the given Line: And — *Secondly*, When the given point is juft (or near) over the *End* of the given Line.

Practice.] IN *the firft Cafe*; Let N O be a Right Line given, and from the point P (over it) let it be required to let fall the Perpendicular P Q. —— *First*, Open the Compaffes to any convenient diftance, greater than the Diftance between P and Q; and fetting one foot in P, with the other draw an obfcure Arch of a Circle, cutting the given Line in the points R and S. —— *Secondly*, Divide the fpace between R and S, into two equal parts in the point Q; So a Right Line drawn from the given point P, to the point Q, fhall be Perpendicular to the Line N O. *Figure* III.

Note, To avoid the dividing of the Space R S, into two equal parts, to find the point Q; if you have room (either above or beneath your Line) you may fet one foot in S, and opening the Compaffes to any convenient diftance, make the Arch Y Y, and removing the Compaffes to R, make the Arch Z Z, croffing the former in Æ; fo a Line drawn through Æ and P, fhall be perpendicular to N O.

In the fecond Cafe; Let V be the point given; — *First*, From any part of the given Line N O; as from T, draw a Right Line to the given point V, which divide into two equal parts in X. — *Secondly*, Set one foot of the Compaffes in X, and with the diftance X T defcribe the Arch (or Semicircle) VOT, cutting the given Line N O in O; fo fhall O be the point, to which from the given point V, if you draw a Right Line, it fhall be a Perpendicular to the Line N O, and from the point V; as was required.

PROBL. IV.

To divide a Right Line *into Two equal Parts, and at* Right *(or Square)* Angles.

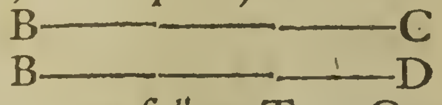
Practice.] LET AB be a Line given, to be fo divided. —— Take in your Compaffes the length of the given Line A B, or any other diftance, greater than half the length thereof; and fetting one foot in the end A, with the other draw the Arch C D E. —— *Secondly*, (the Compaffes being open at the fame diftance) Set one foot in B, and with the other crofs the former Arch (both above and below the Line) in the points F and G: So a Right Line drawn (or a Ruler laid) from F to G, fhall cut the given Line in H; fo fhall the given Line A B be divided into Two equal parts in the point H, and at Right Angles, which was required. *Figure* IV.

PROBL.

PROBL. V.

A Right Line *being given, to draw another* Right Line *which ſhall be* Parallel *thereunto, at any diſtance required, or thro' any* Point *aſſigned.*

Definition.] Right lined Parallels, *are ſuch Right Lines, which being drawn upon the ſame Plain, and infinitely extended on either ſide, would never concur or meet; but always, in all parts, retain an equal diſtance; and ſuch are theſe two Right Lines* BC *and* BD.



In the deſcribing or drawing of Parallel Lines, *there may fall out* Two Caſes *or* Varieties. *As,*

1. *It may be required to draw a Line* Parallel *to another Line, at a certain given diſtance.*
2. *The* Parallel *may be required to be drawn through an aſſigned* Point.

And of this Kind there are two *Varieties:* For,

1. *The given* Point *may be* over *or* under *the given Line. Or,*
2. *It may be* Oblique *to the Line given.*

Figure V. *Practice of the Firſt Caſe.*] LET EF be a Right Line given, and let it be required to draw another Right Line Parallel thereunto, at the diſtance of the length of the Line G.

Firſt, Take in your Compaſſes the length of the given Line G, and ſet one foot in the point E, (or in any other part of the given Line, towards the end thereof) deſcribing the ſmall obſcure Arch IK:---- Then move the Compaſſes to F, (near the other end of the Line) and deſcribe another ſmall and obſcure Arch LM:---- Laſtly, Lay a Ruler to the very top of theſe two Arches, ſo that the Ruler do not croſs but juſtly *touch* either of them; Then if by the edge of the Ruler you draw a Right Line NO, it ſhall be Parallel to the given Line EF, and at the diſtance of the length of G, which was to be done.

Practice of the Second Caſe. LET PQ be a Right Line given, unto which you are to draw another Right Line *Parallel*, which *Parallel* muſt paſs thro' the given point R.

Firſt, Set one foot of your Compaſſes in R, and with the other take the neareſt diſtance to the given Line PQ; which is done by opening or ſhutting of the Compaſſes, till the moveable point of them do only touch the given Line PQ; and there deſcribe the Arch ST.---- *Secondly*, The Compaſſes at the ſame diſtance, ſet one foot in P, (or any point towards the other end of the given Line) and with the other deſcribe the Arch VX.------- *Laſtly*, Through the given point R, and the very top of the Arch VX at Y, draw the Right Line RY, and it ſhall be parallel to the given Line PQ, and ſhall alſo paſs through the given point R; which was required to be done.

Practice of the Third Caſe. LET AB be a Right Line given, to which another Parallel Right Line is given to be drawn, which ſhall paſs through the Point C.

Firſt,

First, Take in your Compaſſes the diſtance from C to B, the end of the given Line.---- *Secondly*, Set one Foot in A, (the other end of the given Line) and with the other deſcribe the obſcure Arch F G.----*Thirdly*, Take in your Compaſſes the length of the given Line A B, and ſetting one Foot in C, with the other deſcribe the Arch D E, croſſing the former in the point H: So a Line drawn from the point C, through the point H, ſhall be parallel to the given Line A B, which was required.

PROBL. VI.

To make an Equilateral Triangle, *whoſe Sides ſhall be all equal to a* Right Line *given*.

Definition.] AN Equilateral Triangle, *is ſuch a Triangle as hath all its Sides equal one to another.*

Practice.] LET Q be the Line given, to which make the Line M O equal; Then, Take the length thereof in your Compaſſes, and ſetting one foot in M, with the other deſcribe the Arch A A.--- Again, Setting one foot in O, deſcribe the Arch B B, cutting the former Arch in N.---- Laſtly, draw the Right Lines N O, and N M, and they ſhall include the Equilateral Triangle M N O, as was required. *Figure* VI.

PROBL. VII.

To make a Triangle *of any three (poſſible)* Right Lines *given*.

LET the three Lines given be C, D, and E.----- *Firſt*, Take the longeſt Line C, in your Compaſſes, and make the Line F G, equal thereunto.---- *Secondly*, Take in your Compaſſes the Line D, and ſetting one foot in G, deſcribe the Arch H H.---- *Thirdly*, Take the Line E, and ſetting one foot in F, deſcribe the Arch I I, croſſing the former Arch in K.---- Laſtly, Draw the Right Lines K F, and K G, and they ſhall conſtitute a Triangle, whoſe three ſides ſhall be equal to the three given Lines, C, D, E, which was required. *Figure* VII.

PROBL. VIII.

To make a Geometrical Square, *whoſe four Sides ſhall be equal to a given* Right Line.

Definition.] A Geometrical Square *is ſuch a Figure whoſe four* Sides *are all equal, and its four* Angles, *all* Right (*or Square)* Angles.

Practice.] LET the given Line be S, take the length thereof, and make the Line T V equal to it, Then on the end T, erect a Perpendicular T X, equal alſo to the Line S.---- Again, Set one Foot of the Compaſſes in X, and with the other deſcribe the Arch P P.--- Alſo, ſet one foot in V, and with the other deſcribe the Arch R R, cutting the former Arch in Z.---- Laſtly, Draw the Lines Z X, and Z V, and you ſhall have conſtituted a *Geometrical Square*, whoſe Sides ſhall be all equal to the given Line S, as was required. *Figure* VIII.

PROBL. IX.

To divide a Right Line *given, into any number of* Equal Parts.

Figure IX. *Practice.* LET the Right line G be the line given, to be divided into five equal parts.

First, Upon any line drawn at pleaſure, as the obſcure line H K, with your Compaſſes opened to any ſmall diſtance, run along the ſame Five times at the figures, 0, 1, 2, 3, 4, 5, (becauſe the line given is to be divided into five parts).—Then, take in your Compaſſes the diſtance from 0 to 5, and with that diſtance, make the *Equilateral Triangle* 5 L 0. —Again, take in your Compaſſes the given line G, and ſet that diſtance from L to M and N, drawing the line M N (which will be equal to the given line G).—Laſtly, Lay a Ruler from L, to the points 1, 2, 3, and 4, in the line H K, and the Ruler will cut the line M N in the points 1, 2, 3 4, dividing the ſame line equal to G, into five equal parts, as was required.

Note, This *Equilateral Triangle* thus made, is capable of dividing any other line into five equal parts, be it either greater or leſſer than this given line G, if the length thereof be ſet from L, on both ſides of the Triangle, and the line drawn croſs from ſide to ſide, as in the figure you ſee the line Q R, which is ſhorter, and the line P O, which is longer than M N (which was equal to our given line G) are both of them divided into five equal parts.

PROBL. X.

How to divide a Right Line *in ſuch parts as another* Right Line *is before divided.*

Figure X. LET the line A B be a Right line unequally divided in the points 10, 20, 30, 40, 50, 60, 70, and 80. And let it be required to divide the two lines, *viz.* C D which is longer, and E F which is ſhorter, into the like unequal parts.

Of the given line A B make an Equilateral Triangle A S B, and extend the ſides S A and S B to G and H, and farther if occaſion be.

Then, take the ſhorter line E F, and ſet it from S to E, and from S to F, and draw the Right line E F.——Alſo take the longer line C D, and ſet that from S to C, and from S to D, and draw the line C D.

Now if you lay a Ruler to S, and to the ſeveral unequal diviſions of the line A B, where the Ruler ſo laid doth croſs the two other lines, it ſhall alſo divide them into the like parts.

PROBL. XI.

To any three Points *given, which lye not in a* Right Line; *to find the* Centre *of a* Circle, *whoſe* Circumference *being deſcribed, ſhall paſs through the given* Points.

Figure XI. LET the three points be A, B, C, —*Firſt*, Set one foot of your Compaſſes in one of the given points A, and extend the other foot to B, another of the given points, and draw the Arch of a Circle G F D. —*Secondly*, (the Compaſſes being kept at the ſame diſtance as before)

Set

Set one foot in B, and with the other foot croſs the former Arch G F D, with two ſmall Marks or Arches, in the points D and F, and draw the right line D F.—*Thirdly*, ſet one foot of the Compaſſes in the third given point C, (they ſtill keeping the ſame opening) and with the other foot croſs the firſt drawn Arch G F D, in the points E and G, and draw the right line E G, croſſing the former right line D F in the point O, So ſhall O be the Centre of a Circle; in which, if you ſet one foot of the Compaſſes, and open the other to any of the three given points, the Circle ſo deſcribed ſhall paſs directly through all the three points A, B, and C, as was required.

PROBL. XII.

Two Points *within a* Circle *being given, how to find the* Centre *of the* Arch *of a* Great Circle, *which ſhall paſs through thoſe given* Points.

Definition.] A Great Circle *upon the* Sphere, *is ſuch a Circle as divideth the* Sphere *or* Globe *into* Two equal parts; *and ſo, the* Arch *of a* Great Circle, *deſcribed upon a* Plain, *is ſuch an* Arch, *as divideth the* Perifery *or* Circumference *of the* Fundamental *or* Primitive Circle *given, into Two equal Parts.*

Practice.] LET G B H D be the *Fundamental* or *Primitive Circle* given, whoſe Centre is C; and let the two points within the ſame, through which the *Arch* of a *Great Circle* is to paſs, be X and Y. *Firſt*, Through one of the given points X, and Centre of the Circle C, draw a right line X C, extending it infinitely towards F; upon this line from the Centre C, erect the Perpendicular C B, and draw the right line B X, cutting the Circle in G, through which point G, and the Centre, draw the Diameter, or right line G C H. *Laſtly*, Through the points B and H draw a right line, extending it till it cut the line X F in R, ſo have you found a third point, *viz.* R, through which the Arch of the great Circle to be deſcribed muſt paſs; and now having three points, X, Y and R, you may through them (by the laſt Problem) draw the Arch of a Circle, namely the Arch A X Y L R, whoſe Centre will be at K, and whoſe Arch will divide the Primitive Circle into two equal parts in the points A and L: And that it doth ſo, is evident, for that the right line drawn from A to L, doth alſo paſs through C the Centre of the Primitive Circle. *Figure XII.*

ASTRO-

ASTRONOMICAL DEFINITIONS.

BEING

The Description of a Material Sphere *or* Globe, *and of the* Points, Lines *and* Circles *thereon described and belonging, how they are situate upon the* Globe, *and to what* Use *each of them serveth.*

WHosoever intends to attain any competent Knowledge in the Art of *Dialling* with Profit, must not be ignorant of the *Rudiments* and *Principles* of *Astronomy*; such, I mean, as relate to the *Sphere* or *Globe*; of which I have lately published a Book of the *Uses* of the *Globes*, Celestial and Terrestial; and to be well acquainted with the several *Points*, *Lines*, and *Circles* thereon described; and to know to what *Use* each of them are appropriate: To the attaining whereof, I premise these following *Definitions*.

I. *Of a* Sphere *in General.*

Figure XIII. Definition.] A Sphere *(as it is defined by* Euclide) *is a solid Figure; made, when the Diameter of a Semicircle abiding unmoved, the Semicircle is turned round about, till it return to the same place from whence it began to be moved:* So that all the Rayes drawn from the Centre to the Superficies of a Sphere are equal.——The *Axis* of which *Sphere* is that fixed *Right Line, about which the Semicircle is moved.* ——*The* Centre *of the* Sphere, *is the same point with that of the Semicircle.*——*And the two extream ends of the Diameter of the Semicircle, are the two* Poles *of the* Sphere.

The Circles *that are described upon the Superficies of a* Sphere, *are in number* Ten: *Of which* Six *are called* Great Circles, *because they divide the whole body of the* Globe *into Two equal parts.*——The other *Four are called* Small *or* Lesser Circles, *for that they divide the body of the* Globe *into Two unequal Parts.*

1. *The* Meridian	7. Azimuths, *or* Vertical Circles
2. *The* Horizon	8. *The two* Tropicks
3. *The* Æquinoctial	9. Parallels *or* Circles *of* Declination
4. *The* Ecliptick	10. Circles *or* Parallels *of* Altitude.
5. *The* Prime Vertical *or* Circle of East & West	
6. *The* Hour-Circles	

Of these Circles, *all but the three last are* great Circles *of the* Sphere, *which divide it into two equal parts; and the two* Tropicks, *the* Circles of Altitude, *and* Declination, *are* smaller Circles, *and divide the* Sphere *into two parts unequally.*

There

There are no more Circles *than these following, Actually described on the Sphere* viz.

1. *The* Meridian			VI Great Circles.
2. *The* Horizon			
3. *The* Equinoctial			
4. *The* Ecliptick			
5. Equinoctial	*Colure*		
6. Solstitial			
7. 8. Tropicks	*Cancer* / *Capricorn*		IV Small Circles
9. 10. Polar	*Artick* / *Antartick*	*Circle*	

Ten Circles *in all*; Six Greater *and* Four Lesser *as was said before.*

As for the Hour-Circles *and* Vertical Circles, *which are mention'd among the* Great Circles *of the* Sphere *in the former Analysis, They are not drawn thereon, because there is an infinite Number of them; and must therefore be left for the Imagination to conceive, according to the position of these Places on the* Globe *which they respect; as well as several other Great* Circles, viz. *The Circles of* Longitude, Position *and many others which are only imaginary.*

Neither are these Lesser Circles *or* Parallels *of* Declination *and* Altitude *fixed thereon for the like Reason.*

But being neverthelefs of Equal Use in the Art of Dialling, *we have therefore Accounted for them among the Rest in the following Definitions.*

Besides these great *and* small Circles, *there are several* Points *of note upon the* Globe: *as* (1.) *The* Zenith, *which is the Point in the Heavens directly over our heads, in what part of the Earth soever we be*; (2.) *The* Nadir, *which is the Point directly under our feet*; (3.) *The* Poles of the World, *about which the Heavens are moved*; (4.) *The Poles of the Ecliptick*; (5.) *the Poles of all other Circles.*

1. *Of the* Meridian.

The *Meridian* is a great Circle of the *Sphere*, which passeth through both the *Poles* of the *World*, and also through the *Zenith* and *Nadir Points*, and crosseth the *Horizon* in the *North* and *South* Points thereof. Unto this Circle (any Day in the year) when the Sun cometh, it is Noon or Mid-day; and when the Moon, Stars or Planets in the Night, come to touch this Circle, they are then said to be upon the *Meridian*, or at the highest they will be that Night. This Circle in the Scheme of this Projection is noted by the Letters ZHNO. *Figure* XIII.

2. *Of the* Horizon.

The *Horizon* also is a great Circle of the *Sphere*, and it is that Circle which divideth the visible part of the Heavens which we see, from the not visible, that is, it divideth the *Sphere* into two *Hemispheres*, the lower, and the higher. To this Circle when either the Sun, Moon, Stars or Planets come to the *East* part, they are then said to *rise*; and when they have passed from the *Easterly* Point by the *Meridian*, and descended to the *Western* part of this Circle, they are then said to *set*. This Circle is represented in the Projection by the right Line HAO.

3. *Of the* Equinoctial.

The *Equinoctial* is a great Circle, and in the *Sphere* it is elevated above the *Horizon* (upon the *Meridian* Circle) so much as is the Complement of the Latitude of the Place. As at *London*, where the Latitude it 51 degr. 32 min. there the *Equinoctial* is elevated 38 degr. 28. min. (which is so much as 51 degr. 32 min. wants of 90 degr.) and it cutteth the *Horizon* in the Points of *East* and *West*. Unto this Circle when the Sun cometh (which is twice every year, namely, about the 10th of *March* and the 12th of *September*) it causeth the Days and Nights to be of equal length all the World over. This Circle is noted in the Scheme with Æ A æ, and cuts the *Horizon* in the point A, which represents both the *East* and *West* points thereof.

4. *Of the Ecliptick.*

This also is a great Circle of the *Sphere*, and (in the *Northern Hemisphere*, where the *North Pole* is visible above the *Horizon*, and the *South Pole* not visible) is elevated above the *Equinoctial* Circle so much as is the Sun's greatest Declination, which is 23 degr. and about 31 min. and is as much depressed below the *Equinoctial* in the *Southern Hemisphere*. This Circle is called by some, *The way of the Sun*; for that the Sun in his motion never swerveth or goeth out thereof; and so his *Longitude* or *Place* is counted in this Line. It cutteth the *Horizon* in the *East* and *West* Point A, as the *Equinoctial* did. It is represented in the *Scheme* by the Line ♋ A ♑, and hath charactered upon it the 12 Signs of the Zodiack; the *Six Northern Signs*, ♈ ♉ ♊ ♋ ♌ and ♍ being on that half which is above the *Horizon*, and the *Six Southern Signs* ♎ ♏ ♐ ♑ ♒ and ♓, on the other half, which is below the *Horizon*.

5. *Of the* Prime Vertical.

The *Prime Vertical*, or Circle of *East* and *West*, (generally called the *Equinoctial Colure*) and then (as the *Sphere* is here projected) the *Meridian* representeth the *Solsticial Colure*, is a great Circle passing through the *Zenith* and *Nadir* Points, and also through the *East* and *West* Points of the *Horizon*. Unto this Circle when the Sun, Moon, Stars or Planets, do (in their Motions) arrive, they are then due *East* or *West*. It is in the Projection signified by the right Line ZAN, passing through Z, the *Zenith*; N, the *Nadir*; and A, the *East* and *West* point of the *Horizon*; and also cutteth the *Equinoctial* in the Points ♈ and ♎.

6. *Of the* Hour-Circles.

The *Hour-Circles* are great Circles of the *Sphere*, meeting together in the *Poles* of the World, and crossing the *Equinoctial* at right Angles, dividing it at every 15 degrees; and then every of those Divisions is one Hour of time: but if they pass through other parts of the *Equinoctial*, dividing it unequally, then do those *Hour-Circles* represent unequal Spaces of time, according to the distance they are from the *Meridian*, or one from another. Of these Circles in the Scheme of the Projection there are four, thus noted, P B S, P A S, P C S, and P D S.

7. *Of the* Azimuth Circles.

The *Azimuth* or *Vertical Circles*, are great Circles of the *Sphere*, meeting together in the *Zenith* and *Nadir* Points, as the *Hour-Circles* do in the *Poles* of the World, and divide the *Horizon* at right Angles, either equally, or unequally, as the *Hour-Circles* did the *Equinoctial*. In the Scheme of the Projection there are four of these *Vertical Circles*, thus noted, Z ☉ N, Z F N, Z A N, and Z G N.

8. *Of the* Tropicks.

The *Tropicks* are Lesser Circles of the *Sphere*, dividing it unequally, and are drawn parallel to the *Equinoctial*, at 23 degr. 30 min. distance therefrom, equal to the Sun's greatest Declination on either side. That *Tropick* which is on the *North-side* is called the *Tropick of Cancer*, to which when the Sun cometh (which is but once in a year, about the 10th of *June)* it maketh the *Longest Days* to all the *Northern* Inhabitants of the World and the *Shortest Nights*. The other *Tropick*, which is on the *South-side* of the *Equinoctial*, is called *The Tropick of Capricorn*, to which when the Sun cometh (which is about the 11th of *December*) it maketh the *Shortest Dayes* and the *Longest Nights* to all *Northern* Inhabitants, and the contrary to all the *Southern* Inhabitants of the World. In the Projection the *Tropick of Cancer* is signified by ♋ I ♋, and the *Tropick of Capricorn* by ♑ K ♑.

9. *Of the* Circles *or* Parallels *of* Declination.

These also are Smaller Circles of the *Sphere*, and are drawn parallel to the *Equinoctial*, towards both the *Tropicks*, and up to them. Those that are on the *North-side* of the *Equinoctial* are called *Parallels of North Declination*, and those that are on the *South-side* of the *Equinoctial* are called *Parallels of South Declination*. Of these *Parallels* there are in the Scheme of the Projection two, one towards the *Tropick of Cancer*, the other towards the *Tropick of Capricorn*, and either of them 20 degrees distant from the *Equinoctial*. The *Northern Parallel of Declination* is noted with ♊ ☉ ♌, and the *Southern* with ♒ E ♐.

10. *Of the* Circles *or* Parallels *of* Altitude.

The Circles of *Altitude* are likewise Small Circles of the *Sphere*, and are drawn parallel to the *Horizon*, as the Circles of *Declination* were to the *Equinoctial*. These *Parallels* are drawn from the *Horizon* towards the *Zenith* point, and upon occasion, in many Cases quite up unto it. By these *Parallels* are measured the *Altitude* or *Height* of the Sun, Moon, and Stars. in the Scheme there is only one of them, and that is expressed by the Letters M E L.

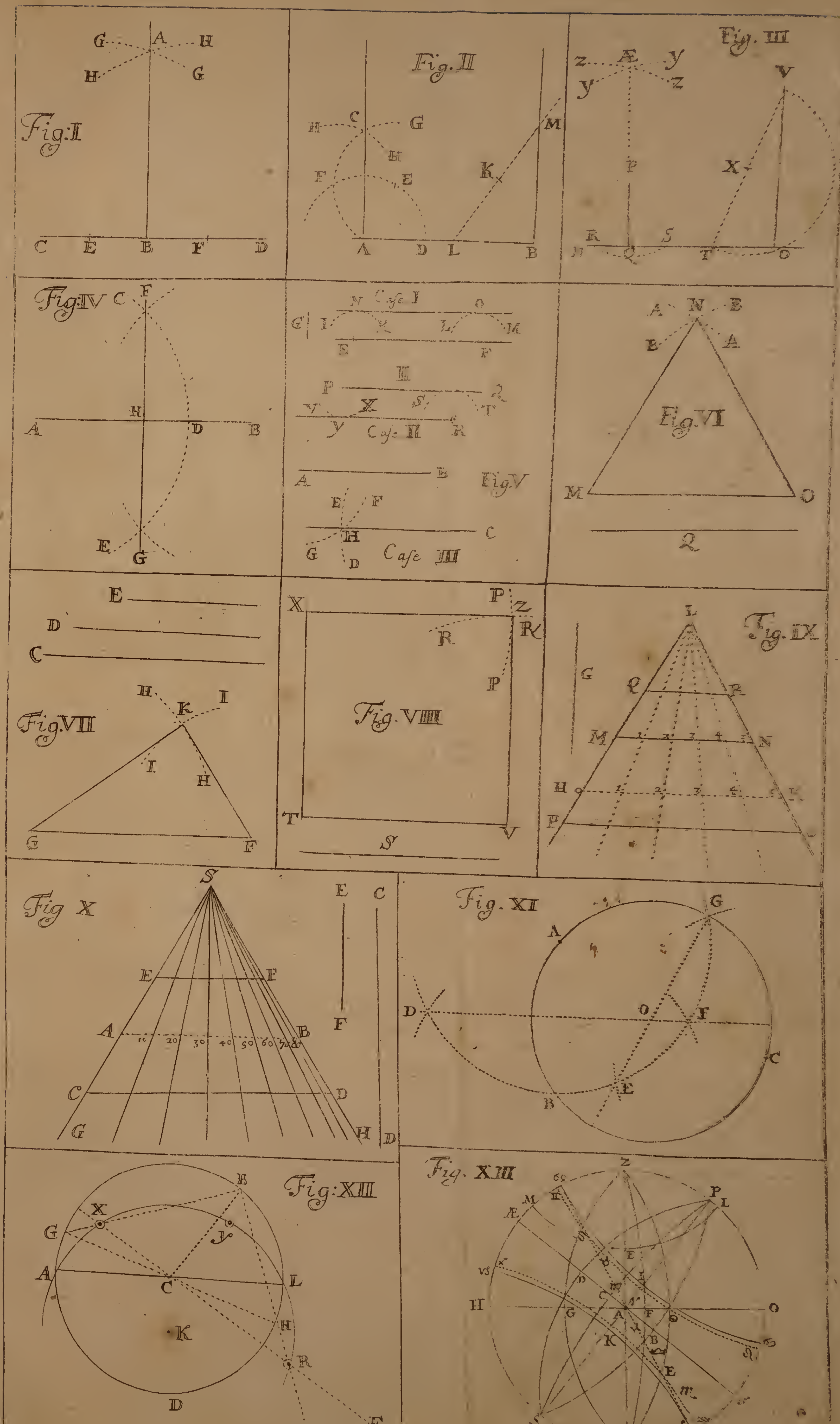
Thus have I given you a brief and plain Description *of the* Circles, both great *and* small, *which we shall have occasion to use in the following* Treatise. *And here note, that every* Circle *of the* Sphere *(both Great and Small) hath his proper* Poles, *which* Poles (*of all the* great Circles) *are* 90 *Degrees, or a* Quadrant *of a* Circle *distant from the* Circle *it self.*

By way of Conclusion to this *Introduction*, I have here inserted two *Tables*, useful and pertinent to the following Tractates: the one of the *Latitudes* of divers principal Places in *England*, *Scotland*, and *Ireland*: The other of the *Sun's Declination*, useful for finding the *Sun's Azimuth*, &c.

An Alphabetical Table of the Latitudes of the chief Cities and Towns in England, Wales, Scotland, *and* Ireland. *By* Robert Morden.

	D.	M.		D.	M.		D.	M.
In ENGLAND.			Oxford	51	46	Dundee	56	31
Bath	51	23	Peterborough	52	36	Glaſgow	56	5
Bedford	52	8	Reading	51	28	Irwin	55	50
Briſtol	51	28	Rocheſter	51	25	Larnack	55	51
Buckingham	52	0	Saliſbury	51	3	Montroſſe	56	44
Bury *in* Suff.	52	20	Shrewsbury	52	46	Nairn	57	30
Cambridge	52	3	Southampton	50	54	Perth *or* St.*J.*	56	32
Canterbury	51	20	Warwick	52	21	Sterling	56	15
Carlile	54	59	Wincheſter	51	4	Withern	54	57
Cheſter	53	17	Worceſter	52	15	*In IRELAND.*		
Chicheſter	50	48	York	53	58	Ardmagh	54	23
Colcheſter	51	58	*In WALES.*			Athlone	53	21
Coventry	52	28	Aſaph	53	20	Bantry	51	30
Derby	52	58	Bangor	53	21	Belfaſt	54	41
Dorcheſter	50	41	Beaumorice	53	24	Caſhel	52	24
Durham	54	50	Brecknock	52	6	Catherlagh	52	46
Ely	52	25	Cardiff	51	30	Clare	52	42
Exeter	50	42	Cardigan	52	12	Cork	51	43
Gloceſter	51	54	Carmarthen	51	56	Craven	54	1
Guilford	51	12	Carnarvan	53	18	Drogheda	53	44
Hertford	51	49	S. Davids	52	0	*DUBLIN*	53	20
Hereford	51	8	Denbiſh	53	18	Donnegal	54	40
Huntington	52	10	Harlech	52	58	Dundalk	54	2
Ipſwich	52	8	Landaaf	51	31	Dungarvan	51	57
Kendale	54	22	Montgomery	52	39	Galloway	53	12
Lancaſter	54	28	Pembrook	51	45	James Town	53	53
Lanceſton	50	49	Radnor	52	30	Kildare	53	8
Leiceſter	52	40	Welchpool	52	43	Kilkenny	52	34
Litchfield	52	50	*In SCOTLAND.*			Kinſale	51	30
Lincoln	53	15	Aberdeen	57	6	Knockfergus	54	50
LONDON	51	32	St. Andrews	56	24	Limrick	52	33
Monmouth	51	52	Berwick	55	50	Letrim	53	58
Newcaſtle	55	3	*EDINGBRUGH*	56	4	Londonderry	55	4
Northampton	52	14	Dunblain	56	20	Longford	53	42
Norwich	52	42	Dunbritton	56	10	Slego	54	17
Nottingham	52	59	Dunbar	56	3	Waterford	52	9
Okeham	52	41	Dunfries	55	3	Wexford	52	17

A



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A TABLE *shewing the Sun's* Declination *for every day of the Year, serving for the more ready finding of the Sun's* Azimuth.

A Table of the Sun's Declination.

Days.	Janu.		Febr.		March.		April.		May.		June.		July.		Aug.		Sept.		Oct.		Nov.		Dec.	
	d.	mi.	d.	mi.	d.	mi.	d.	mi.	d.	mi.	d.	mi.	d.	mi.	d.	mi.	d.	mi.	d.	mi.	d.	mi.	d.	mi.
1	21	44	13	46	3	24	8	36	18	5	23	12	22	8	15	12	4	24	7	15	17	40	23	9
2	21	33	13	26	3	0	8	58	18	20	23	16	22	0	14	54	4	2	7	38	17	56	23	13
3	21	23	13	5	2	37	9	20	18	35	23	19	21	51	14	36	3	38	8	0	18	12	23	17
4	21	13	12	45	2	13	9	42	18	50	23	22	21	42	14	17	3	15	8	22	18	28	23	20
5	21	2	12	25	1	49	10	3	19	4	23	25	21	32	13	58	2	52	8	45	18	43	23	23
6	20	50	12	4	1	25	10	24	19	18	23	27	21	22	13	39	2	29	9	7	18	58	23	26
7	20	38	11	43	1	1	10	45	19	31	23	29	21	12	13	20	2	5	9	29	19	13	23	28
8	20	26	11	21	0 South.	38	11	0	19	44	23	30	21	2	13	1	1 North.	42	9	51	19	27	23	30
9	20	13	11	0	0	14	11	27	19	57	23	31	20	51	12	41	1	19	10	13	19	41	23	31
10	20	0	10	38	0	10	11	47	20	10	23	32	20	40	12	21	0	55	10	35	19	55	23	31
11	19	46	10	16	0	33	12	7	20	22	23	31	20	28	12	1	0	32	10	56	20	8	23	31
12	19	32	9	54	0	57	12	28	20	34	23	31	20	16	11	41	0	8	11	18	20	21	23	31
13	19	18	9	32	1 North.	21	12	48	20	45	23	30	20	4	11	21	0 South.	16	11	39	20	34	23	29
14	19	3	9	10	1	44	13	7	20	56	23	29	19	51	11	9	0	39	12	0	20	46	23	27
15	18	48	8	48	2	8	13	27	21	7	23	28	19	38	10	39	1	3	12	21	20	58	23	25
16	18	33	8	25	2	31	13	46	21	17	23	26	19	25	10	18	1	26	12	41	21	9	23	22
17	18	17	8	3	2	54	14	5	21	27	23	23	19	12	9	57	1	50	13	2	21	20	23	19
18	18	2	7	40	3	18	14	24	21	37	23	20	18	58	9	36	2	13	13	22	21	31	23	16
19	17	45	7	17	3	41	14	42	21	46	23	17	18	43	9	15	2	37	13	42	21	41	23	12
20	17	28	6	54	4	5	15	1	21	55	23	14	18	29	8	53	3	0	14	2	21	50	23	7
21	17	11	6	31	4	28	15	19	22	4	23	10	18	14	8	31	3	23	14	21	22	0	23	2
22	16	54	6	8	4	51	15	37	22	12	23	6	17	59	8	9	3	47	14	41	22	9	22	57
23	16	36	5	45	5	14	15	54	22	20	23	1	17	44	7	47	4	10	15	0	22	17	22	51
24	16	18	5	21	5	37	16	12	22	27	22	55	17	28	7	25	4	33	15	19	22	25	22	44
25	16	0	4	58	6	0	16	29	22	34	22	50	17	12	7	3	4	57	15	37	22	33	22	37
26	15	42	4	34	6	22	16	46	22	41	22	44	16	56	6	41	5	20	15	55	22	40	22	30
27	15	23	4	11	6	45	17	2	22	47	22	37	16	39	6	18	5	43	16	13	22	46	22	22
28	15	4	3	47	7	7	17	18	22	53	22	31	16	22	5	56	6	6	16	31	22	52	22	14
29	14	45	.	.	7	30	17	34	22	58	22	23	16	6	5	33	6	29	16	49	22	58	22	5
30	14	26	.	.	7	52	17	50	23	3	22	16	15	48	5	10	6	52	17	6	23	4	21	56
31	14	6	.	.	8	14	.	.	23	8	.	.	15	30	4	47	.	.	17	23	.	.	21	49

The End of the *Introduction.*

PLAIN DIALLING, *DEMONSTRATED:*

By Projecting the Sphere *in Plano*, upon the Plain of the *Horizon*, ſuitable to any *Latitude*; and from thence to draw the *Hour-Lines*, *Stile* and *Sub-Stile*, proper to any *Plain*, in their true Places and Poſitions.

ALSO

Upon the *Projection*, to expreſs the ſeveral *Spherical Triangles* from which all the *Requiſites* belonging to any *Dial* are to be *Calculated*; And how to *Calculate* the ſame.

LIKEWISE,

How to Meaſure the *Sides* and *Angles* of thoſe *Triangles* upon the *Projection* it ſelf.

The Firſt TRACTATE.

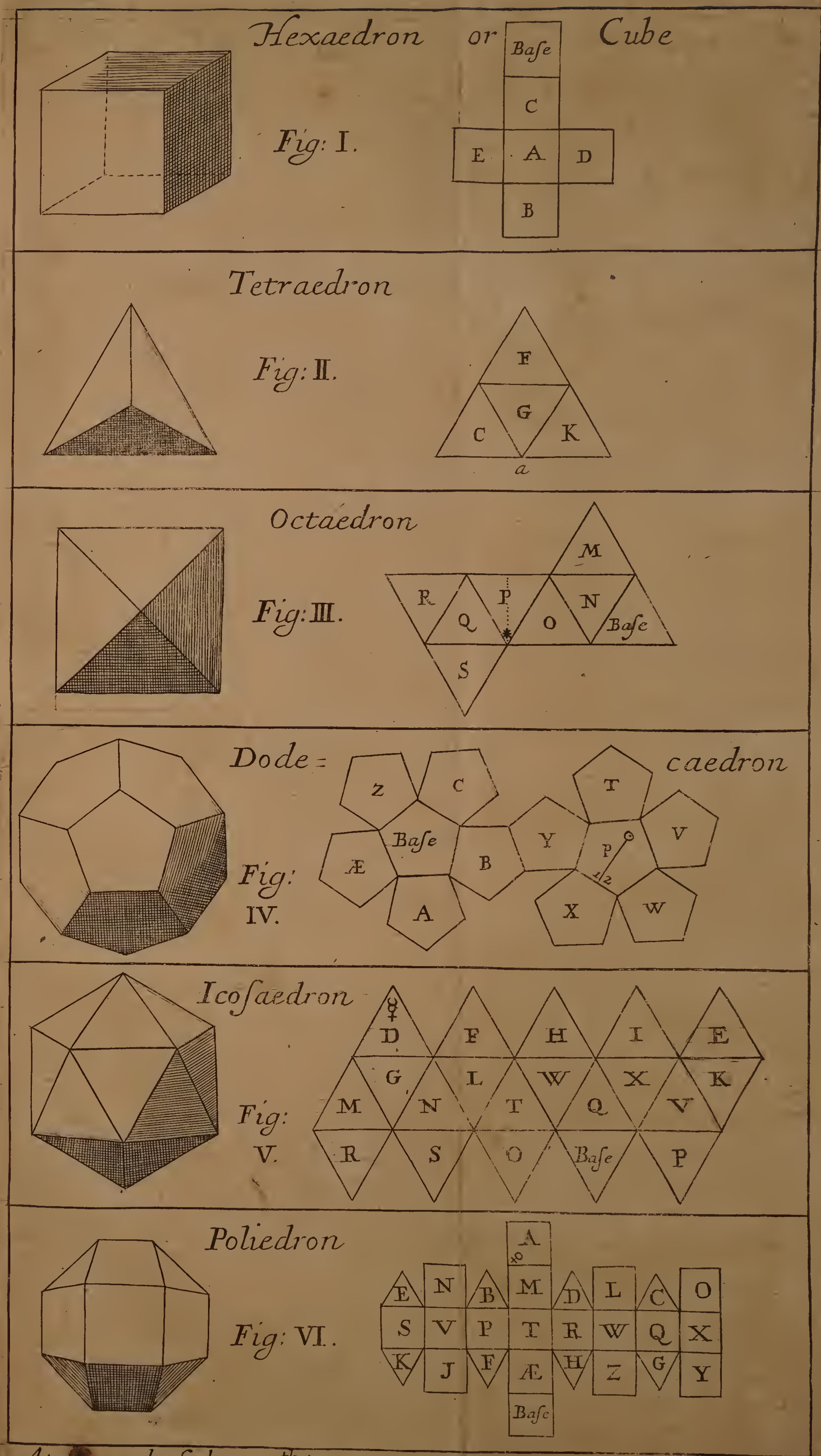
CHAP. I.

Of the Lines *or* Scales *of* Natural Sines, Tangents, Secants, Half Tangents, *and* Chords, *often mention'd, and made uſe of in this Book; Their conſtruction or making, ſhewing how they are deduced from a* Circle *or* Semicircle; *and from thence transferred unto* Streight Lines, *and ſo may properly be termed* Circular Scales *or* Lines.

Definition.] THe *Circumference of every* Circle (*be it great or ſmall*) *is divided into* 360 *equal* Parts, *called* Degrees; *and each of thoſe* Degrees *is again divided (or ſuppoſed ſo to be) into* 60 Minutes*So that a* Semi, *or Half* Circle, *contains* 180 *degrees, and a* Quadrant, *or Fourth part of a* Circle, *contains* 90 *degrees.*

The Diameter *of a* Circle *is a right Line drawn through the* Center *of the* Circle, *dividing the* Circle *into Two equal Parts.*

The Semi-Diameter *of a* Circle, *is one half of the* Diameter, *and is for the moſt part called the* Radius.



At the end of the 14.th Tractate to fold out.

Practice.] FRom these Definitions of a *Circle* and its parts, I proceed to shew the manner of Production of the fore-mention'd *Circular Scales* or *Lines*, of *Sines*, *Tangents*, &c. there-from. *Figure* I.

1. Let there be a *Semicircle* described of any Radius whatsoever, (suppose of two Inches, as in the Figure) which *Semicircle* let be VRS, Then is VS the *Diameter* of the *Semicircle* VRS, and the *Perpendicular* raised from the *Center* or middle of the *Diameter* ⊙ R, is the *Semidiameter* of the *Circle*, which divides the *Semicircle* into two *Quadrants*, viz. ⊙RS, and ⊙RV.

2. Divide the two *Quadrants* ⊙RS and ⊙RV, each of them into 90 equal parts or *Degrees*, as in the Figure is done, beginning at V and S, and ascending upwards towards R; numbring them by 10, 20, 30, *&c.* to 90; as there you may see done.

3. If you draw Right Lines from 10 in the one *Quadrant*, to 10 in the other *Quadrant*, and from 20 in one, to 20 in the other, and so upwards, till you come to R; those Lines 10. 10, 20. 20, *&c.* will be all of them *Parallel* to the *Diameter* VS; and will cut or divide the *Radius*, or *Semidiameter* R⊙, into 90 unequal *Parts* or *Divisions*; which Line (so unequally divided) is a *Line* or *Scale* of *SINES*.

4. Upon the Point S, erect a Perpendicular to VS, namely ST: Then, if from the *Center* ⊙, you draw Right Lines through every degree of the *Quadrant* (as here is through every Tenth) you shall divide the Perpendicular Line ST, into unequal parts, at the points 10, 20, 30, *&c.* up to T, and farther if you go on: So shall this unequally divided Line S T, be a *TANGENT Line*, or *Scale*: And from the beginning thereof at S, to 45 degrees thereof, will be equal to the *Radius* of the Circle, or to the whole *Scale* of *Sines* ⊙ R.

5. If from the *Center* ⊙, and from every degree of the *Quadrant* (or tenth degree thereof) as here is done, you draw Right Lines to the *Tangent Line*, those Lines so drawn shall be *SECANTS*: As the Line ⊙ET, (drawn from the *Center* ⊙ through 60 degrees of the *Quadrant* RS) is the *Secant* of 60 deg. And the Line drawn from ⊙, thro' 50 deg. of the *Quadrant*, to 50 degrees in the *Tangent Line*; that Line is the *Secant* of 50 deg. And so of all the Rest.

6. Draw the Line VR, and with one foot of your Compasses placed in V, open the other to 80 deg. in the *Quadrant*, and transfer that distance of your Compasses, to the Right Line VR, by drawing of the small Arch 80. 80. cutting the Line VR in 80 deg. the like for 70, 60, 50, *&c.* So shall the Line VR be unequally divided into 90 parts, and so becomes a *Line* or *Scale* of *CHORDS*. 60 degrees of this *Scale* of *Chords*, viz. from V to 60, is equal to the whole *Line* of *Sines*; and is called *The RADIUS* of the *Line*, or *Scale* of *Chords*; it being equal to the *Semidiameter* of the *Circle* ⊙ R.

7. If 45 degrees of the *Tangent Line*, viz. from S to 45, be divided as here it is, and 5 deg. be numbered with 10, and 10 with 20, and 20 with 40, then will 45 deg. be 90 deg. and a line so divided is called a *Line* or *Scale* of *HALF TANGENTS*.

These Lines here described may most conveniently, be put upon a *Ruler* of 8 or 12 Inches long, together with some other *Lines*, or *Scales* of *Equal Parts*, *Chords* to several *Radius*'s, and such like; which will be a convenient Instrument for any Artist to have about him: a figure of such a Ruler, with such Scales upon them is graduated in Figure II.

Figure. II. And Note, That these *Scales* being put upon a straight *Ruler*, as in the *Figure*, they will serve to *Project* and Work several other *Conclusions*, however they only suit with the particular *Radius* to which they are made: But if you put them upon a *Sector* with a *French Joynt*, they will be far more convenient for use; for then, they may be applied to any *Radius*, not exceeding the length of the *Sector*'s Legs.

CHAP. II.

How to Project the Sphere in Plano *suitable to any* Latitude, *upon the* Plain *of the* Horizon.

HAving already made way for the more orderly proceeding in the matter principally intended in this *First Tractate*, namely *Dialling* deduced from the *Sphere* it self, which of all others is the most Rational and Demonstrative, the Subject of this second Chapter shall be to shew how to *Project* the *Circles* of the *Sphere* upon a *Plain*, suitable to any *Latitude* or *Horizon* required. This may be performed several ways; Namely, (1) By help of a Line or Scale of equal Parts divided into 10000, of equal length with the *Radius* or Semidiameter of the Primitive Circle you Project upon. (2) By the help only of a *Scale* of *Chords* of the same *Radius* with the Circle you Project upon. (3) And best of all by the *Scales* of *Sines*, *Tangents*, *Secants*, *Half Tangents*, and *Chords*; all made to the same *Radius*, or Semidiameter of the Circle you project upon. I shall say nothing of the First of these Three ways, because in this Book there are no *Tables* of *Natural Sines*, *Tangents*, or *Secants*; nor of the Second, because the Lines in many Cases will extend to almost infinite Excursions, but shall satisfie my self, aud the Reader with the Third and Last way namely by the *Lines* or *Scales*, of *Natural Sines*, *Tangents*, *Secants*, *Half Tangents*, and *Chords*, joyntly used together; the making whereof hath been already taught in the former Chapter. To proceed then, —— Let it be required to *Project* the *Sphere* suitable to the *Horizon* of *London*, whose Latitude is 51 deg. 32 min.

Figure. III. First, Open your Compasses to the *Radius* of your *Sines*, *Tangents*, *Secants*, *Half Tangents*, and *Chords*, which are all of one *Radius* (*viz.* Two Inches) and with that extent upon the Point Z, as a Center describe a Circle, which I call the *Fundamental* or *Primitive Circle*, and let it represent the *Horizon* of *London*.

Secondly, Divide this Circle into four equal parts, by help of the two Diameters, drawn at right Angles, namely the line NZS, representing the Meridian, and the Line WZE, representing the *Prime Vertical Circle*, or *Azimuth* of *East* and *West*.

Thirdly, Forasmuch as the Latitude of *London* is 51 deg. 32 min. take 38 deg. 28 min. (the Complement thereof) out of the Scale of Half Tangents, and set them upon the Meridian N Z S, from Z to P, so shall P be the *Pole* of the *World*, and the Center where all the *Hour-Circles* must meet and a Circle drawn which shall pass through the three points W, P, E; shall be the *Hour-Circle* of *Six*. To find the Center whereof (which

(which will always fall in the Meridian Line NZS, extended if need be) take the Secant of 51 deg. 32 min. out of the Scale of Secants, and set it upon the Meridian from P, it shall give you the Point B: Or the Tangent of 51 deg. 32 min. set upon the Meridian from Z, shall give the same Point B as before; which Point is the Center of the Six a Clock Circle.

Fourthly, In regard that the *Equinoctial Circle* is 90 deg. distant from the *Pole* of the *World*, and 51 deg. 32 min. distant from the *Zenith*: Take 51 deg. 32 min. out of the Scale of *Half Tangents*, and set them upon the Meridian from Z to Æ, so shall Æ be a Point in the Meridian, through which, and the Points W and E in the *Horizon*, the *Equinoctial Circle* must pass. And to find the Center thereof, the Secant of 38 deg. 28 min. set from Æ, or the Tangent of 38 deg. 28 min. set from Z upon the Meridian, will either of them give the Point C for the Center of the Equinoctial Circle W Æ E.

Fifthly, for the describing of the *Hour-Circles*, the Point B (before found) being the Center of the *Hour-Circle* of *Six*: Through that Point B, draw a Line at length, as K B K, which must be Perpendicular to the Meridian N Z S, and consequently Parallel to the *Prime Vertical* Circle W Z E, and in drawing this Line true (according to these conditions) you must be very careful, for the true drawing of all the other *HOVR CIRCLES* do wholly depend thereon, the *Centers* of all of them being in this Line. And for the finding of the *Centers* in this Line, you must.

Sixthly, Take 45 deg. out of your *Tangent Scale*, and set it from P to R upon the Meridian Line, and draw an obscure Line through R, Parallel to W E, as the Line R H: Upon this Line, set the Tangent of 15 deg. from R to 5.—Also the Tangent of 30 deg. from R to 4.—Likewise the Tangent of 45 deg. from R to 3.—The Tangent of 60. deg. from R 2.—And lastly, the Tangent of 75 deg. from R to 1.

Seventhly, Lay a Ruler from P to 5, in the Line RH, and it will cut the Line B K in the Point V, which Point will be the Center, by which to describe the *Hour-Circle* of *Five*, for one foot of the Compasses placed in V, and extended to P, will describe the Arch 5 P 5, for the *Hour-Circle* of *Five*. And the distance B V, being set upon the Line B K, on the other side of the Meridian, from B to VII, the same extent of the Compasses as before, one foot being placed in VII, and extended to P, will describe the Circular Arch 7 P 7, for the *Hour-Circle* of *Seven*.—And in this manner, if you lay a Ruler from P to 4, in the Line R H, it will cut the Line B K in IIII, and the Point IIII will be the Center whereby to draw the *Hour-Circle* of *Four*, viz. The Arch 4 P 4. And the distance B IIII, being set on the other side of the Meridian, from B to VIII, shall there give you the Center whereby to describe the Circle 8 P 8, for the *Hour-Circle* of *Eight*.—And in the same manner, must you do for the Hour Circles of 3 and 9.—2 and 10.—1 and 11, whose *Centers* will all be in the Line B K, extended both ways:—And in the same manner as the *Whole Hours* were drawn, so may the *Halves*, and *Quarters* be drawn, by allowing 15 deg. of the Tangent Scale for *One hour*, 30 deg. for *Two hours*, &c.—7 deg. 30 min. for *half an Hour*, and 3 deg. 45 min. for *One quarter of an Hour*, and setting those distances upon the Line RH, and afterwards transferring them to the Line B K, as you see done in the Figure of the *Projection*; you shall have

Centers for the Halves and Quarters of Hours alſo.——And becauſe the Centers of thoſe *Hour-Circles* which come near the *Meridian*; as the Hours of 11 and 1, and the *halves* and *quarters* between them and the *Meridian*, falling upon the Line B K will be very remote, and beyond the reach of ordinary Compaſſes, therefore for the deſcribing of them, Artificers, and other Artiſts, have an Inſtrument which they call a *Bow*, by which they draw them with great facility.

A Synopſis of this Projection.

Figure III. The Primitive Circle N E S W, repreſents the *Horizon*,; whoſe Latitude is 51 deg. 32 min.

Z is the Zenith.

N Z S the Meridian.

W Z E the Prime Vertical Circle, or Azimuth of Eaſt and Weſt.

P the Pole of the World, whoſe diſtance from Z is = the half Tangent of 38 deg. 28 min. the Complement of the Latitude.

W Æ E is the Equinoctial, whoſe Diſtance from Z is = the half Tangent of 51 deg. 32 min.

C the Center of the Equinoctial Circle, whoſe diſtance from Æ is = the Secant of 38 deg. 28 min. Or from Z is = the Tangent of 38 deg. 28 min. the Complement of the Latitude.

B is the Center of the Equinoctial Colure or Hour Circle of Six, WPE, whoſe diſtance from P is = the Secant of 51 deg. 32 min. Or from Z is = the Tangent of 51 deg. 32 min. the Latitude.

The Centers of the Hour-Circles are all found in the Line K B K. extended both ways, as is ſhewn in the Deſcription.

I might have proceeded farther in this *Projection*, by ſhewing how to inſcribe the *Tropicks*, the *Parallels* of the *Signs*, or of the *Sun's Declination*: The *Ecliptick*, the *Circles* of *Altitude*, and *Azimuth* Lines, with others relating to the *Sun*'s *Courſe*; but there being no occaſion to make uſe of them in this place, I ſhall reſerve the manner of inſerting them and others of the like Nature into the *Projection*, becauſe it will be done hereafter, when I ſhall come to ſhew the manner how to inſcribe thoſe *Circles*, and *others* upon *Dial-Plains*.—— Let it ſuffice therefore, in this place, that I ſhew how to *repreſent* and *lay down* upon the *Projection* any *Plain* upon which a *Dial* may be made, and how to find the *Centers* and *Poles* of ſuch *Plains* ſo deſcribed: And alſo to meaſure the *Sides* and *Angles* of ſuch *Spherical Triangles* as are upon the *Projection*: But firſt, it will be requiſite that I give you an account in a ſhort Analyſis

CHAP.

CHAP. III.

Of the Denominations and Situations of the ſeveral ſorts of plains upon which Dials are uſually made.

DIALS may be made upon any plain Superficies, and all plain Superficies are poſited in one or other of theſe three Poſitions, *viz.* either *Parallel*, *Perpendicular*, or *Oblique* to the *Horizon* of the Place, wherein the Plain is ſeated, and all the Hour-Lines drawn upon any Plain, are great Circles of the Sphere, which being projected upon a plain Superficies, become Strait Lines.

Now the Art of Dialling conſiſteth chiefly in the finding out of theſe Lines, and their true diſtances from each other, the which do continually vary, according as the Plains upon which they are deſcribed, or projected, are ſituated in reſpect of the HORIZON of the Place.

Of theſe Plains there are but 3 Varieties, *viz.*

1. *Parallel* to the Horizon, as is the *Horizontal* (which I call *Vertical*) Plain only.
2. *Perpendicular* to the Horizon, and ſuch are all erect Plains. which be either
   - Direct as
     - North and South.
     - Meridional, or Eaſt and Weſt.
   - Or Declining.
3. *Reclining* from the Zenith or Inclining to the Horizon. and theſe are either
   - Direct
     - North
     - South
     - Eaſt
     - Weſt
     - Re- / In- clining.
   - Or
   - Declining &
     - Reclining
     - Inclining

Now in the making of particular Dials, which are in number 25, I reduce them to 17, by ſupplying the *Inclining* Plains from their oppoſite *Recliners*, as being indeed the ſame.

And to avoid miſtakes, which may poſſibly ariſe by comparing my Examples with other Authors, or others with mine; you are to take notice, That I denominate all my Plains from the ſight (or the Poſit ons) of their Axis in the Heavens, and not from the Circles of the Sphere in which they lie. Therefore.

Thoſe

Those Plains which most Writers call	I call	Because their Poles do lye in the
Horizontal	Vertical	Vertex or *Zenith* Point.
Vertical	North, South — Direct	North, South — Points of the *Hor.*
Meridian	East, West — Direct	East, West — Points of the *Hor:*
Equinoctial	Polar	*Poles* of the World
Polar	Equinoctial	*Equinoctial* Circle.

Again, All leaning Plains whether direct or declining, whose upper faces behold the *Zenith*, I call *Recliners*, and the neather, or under faces of them, which respect, or look down to the *Nadir*, I call *Incliners*.

This Distinction being made, the Plains, of which the Examples following are given, are thus denominated.

1. Vertical or Horizontal.
2. South and North direct.
3. Meridian, Or East and West direct.
4. South and North, declining { East or West }
5. East and West direct { Reclining, or Inclining. }
6. Equinoctial, or South Reclining or Inclining, to the Pole.
7. 8. } South direct Reclining or Inclining { less / more } than the Pole.
9. Polar, or North Reclining or Inclining to the Equinoctial.
10. 11. } North direct Reclining or Inclining { less / more } than the Equinoctial.
12. } Equinoctial, or South Declin. East or West { Reclining / Inclining } to the Pole.
13. 14. } South Declin. East or West, Reclin. or Inclining { above / under } the Pole.
15. Polar or North decl. East or West, Recl. or Incl. to the Equator.
16. 17. } North declining East or West Reclining or Inclining { above / under } the intersection of the Meridian and Equator

CHAP.

CHAP. IV.

How to describe upon the Projection, *any* Plain *mentioned in the former* Chapter; *and to find the* Centers *and* Poles *of all such* Plains.

THe Plains that I shall lay down for *Examples* upon the *Projection* in this place, shall be such as are treated of in the following Discourse: I intended to have laid them all down, but finding the *Diagram* to be incumbered with multiplicity of *Circles*, *Lines*, and *Letters*, I will content my self, and satisfie the *Reader*, by giving an *Example* of *One* of each *Kind*, and the rather, because (when I come to delineate and draw the Dial from the Projection) the same (in effect) will be repeated again: Therefore,

FIrst, The *Horizontal*: This Plain upon the *Projection* is represented by the *Primitive Circle* thereof *viz.* W N E S. The *Center* and *Poles* whereof are in the Point Z the *Zenith*, which Point is 90 deg. distant from the *Plain* in all places thereof, and so must the *Poles* of all *Plains* be. *Figure* III.

2. The *Erect Direct North* and *South Plains*, are represented by the Line W Z E; for these *Plains* beholding the direct *North* or *South* Points, the *Plain* it self must needs lie in the *Azimuth* of *East* and *West*. The *Poles* of the *Plain* are N and S, which Points are removed from the *Plain* 90 deg.

3. The *South Erect Plain, Declining to the West* 35 deg. To describe this *Plain* upon the *Projection*, Take 35 deg. out of the *Scale* of *Chords*, and set them from W to *a*, and from E to *a*, (because the Plain declines *Westward*) and draw the Line *a* Z *a*, for your declining Plain.——Then for the *Pole* thereof, take 90 deg. out of the *Chord-Line*, and set them from *a* to *b*, and from *a* to *b*, both ways upon the *Primitive Circle*, so shall *b b* be the two *Poles* of the *Declining Plain*; for a Line drawn from *b* to *b*, would cut the *Plain* at right *Angles* in Z, and be every where 90 deg. distant from the Plain.

4. The *Direct West Plain Reclining* 35 deg. Take 35 deg. the *Reclination*, out of your *Scale* of *Half Tangents*, and set them from Z to *c*, towards W, (because it is a West Plain, or towards E, had it been an East Plain) so have you three Points, N, *c* and S, through which to draw the Circle N *c* S, representing your *Reclining Plain.*——Now for the Pole of this Plain, Take 55 deg. the Complement of the Reclination, out of your Scale of *Half Tangents*, and set it from Z to *d*, upon the Line Z E, so shall *d* be the Pole of the Plain N *c* S. And for the Center of it, take the Secant of 55 deg. the Complement of the *Reclination*, and set them from *c* upon the Line *c* E continued, and that shall give you the Point, upon which to describe the Circle N *c* S, representing your *Reclining Plain.*

5. *The Direct South Plain Reclining* 70 deg. may be thus inserted. The *Half Tangent* of the Reclination 70 deg. set from Z to *f*, shall give the intersection of the *Plain* with the *Meridian*: And the *Secant* of 20

 deg.

deg. (the Complement of the Reclination) ſet from *f* to *g*, ſhall give the Center, whereby to deſcribe the *Reclining Plain* W *f* E. alſo, The *Half Tangent* of 20 deg. (the Complement of the *Reclination*) ſet from Z to *h*, ſhall give *h*, for the *Pole* of the *Plain*.

This *Plain* paſſeth between the *Pole* and the *Horizon*.

6. The *North direct Plain*, *Reclining* 70 deg. may be thus inſerted: Take the *Half Tangent* of the *Reclination*, 70 deg. and ſet it from Z to *m*, alſo take the *Half Tangent* of the Complement thereof, 20 deg, and ſet it from Z to *n*, ſo ſhall *m* be the interſection of the *Plain* with the *Meridian*, and *n* the Pole thereof; and the *Secant* of the Co-Reclination 20 deg. ſet from *m*, ſhall give a Point a little above P (the Pole of the World) for the Center, whereby to deſcribe the *Reclining Plain* W *m* E.

This *Plain* paſſeth between the *Equinoctial* and the *Horizon*.

7. We come now to the laying down, or deſcribing, ſuch Plains upon the *Projection*, as do both *Decline* and *Recline*; and for our *Example*, Let us take a South Plain, Declining Eaſtward 30 deg. and Reclining 55 degrees. —To deſcribe this Plain upon the *Projection*. —Take the Declination of the Plain 30 deg. out of a Scale of *Chords*, and ſet it from E to D, and from W to G; alſo ſet it from N to I, and from S to L; ſo ſhall the Line D G repreſent the *Baſe* of the Reclining Plain and the pricked Line I L the *Axis* thereof: Now the Reclination being 55 deg. the *Half Tangent* thereof ſet from Z to *s*, gives the point of the Plain, and its Complement 35 deg. ſet from Z to *t*, gives the *Pole* of the Plain · and the Secant of 35 deg. (the *Co-Reclination*) gives the point *r*, for the Center of the *Reclining Plain* G *s* D: The which *Plain* paſſeth between the *Pole* and the *Horizon*.

8. The laſt *Example* ſhall be of a *North Declining Reclining* Plain, *viz North*, *Declining Weſt* 60 deg. and *Reclining* 54. deg. For the deſcribing of which Plain upon the *Projection*; Take 60 deg. the Plain's *Declination* out of a *Scale* of *Chords*, and ſet it from E to M, and from W to O and draw the Line M O, for the *Baſe* of the *Reclining* Plain: Alſo ſet 60 deg. from S to Q, and from N to V, and draw the pricked Line V Q for the *Axis* of the Reclining Plain. The *Baſe* and *Axis* being found, Take the *Reclination* 54 deg. out of the *Scale of Half Tangents*, and ſet it from Z to *z*, for the Plain; and its Complement 36 deg. ſet from Z to *æ*, will give the *Pole* of the Plain, and the *Secant* of the Co-Reclination 36 deg. being ſet from *z*, upon the Line Q V, will give the Center whereon to deſcribe the Plain M *z* O; the which Plain paſſeth between the *Equator* and *Horizon*.

How the Pole *of any* Great Circle *deſcribed upon the* Pro*jection may be found.*

Figure III. LEt the pricked Arch O * M be the Arch of a great Circle deſcribed upon the Projection: To find its Pole, Draw a Right line from the two points where the Arch toucheth the primitive Circle, as from the Points O and M, which Line O M (if the Arch be the true Arch of a great Circle,) will paſs through Z the Center. —From M or O, ſet 90 deg. to V and Q, and draw the pricked Line V Q cutting the deſcribed Arch in the point *. —Then lay a Ruler from M to *, and it will cut the primitive Circle in ♓, ſet 90 deg. from ♓ to ♒, and a Ruler laid

laid from M to ♒, will cut the Line V Q in ♉, so is ♉ the Pole of the Arch of the Great Circle O * M: And in this manner may the Pole of the Arch of any Great Circle be found:

Note here, (because hereafter there will be often occasion for it) That, if the Arch of a Great Circle, whose Pole you seek, do pass thro' P the Pole of the World, the Pole of that Circle will be in some part or other of the Æquinoctial Circle W Æ E.

CHAP. V.

How the Sides *and* Angles *of* Spherical Triangles *are to be Measured upon the* Projection.

BY the Intersection of these Arches of *Great Circles* upon the *Projection* are constituted divers *Spherical Triangles*, some *Right-Angled*, some *Quadrantal*, and others *Oblique-Angular*. The *Sides* and *Angles* of all which, may be measured by help of the Scales of *Chords* and *Half Tangents*: But to avoid confusion of Letters in the Scheme, I will make choice only of one Right-Angled Triangle, namely, M *d* E Right-Angled at E.

For the Right Angled Triangle M *d* E;

1. The *Side* ME, is measured by taking the distance of ME in your Compasses, and applying it to a *Scale* of *Chords*, so shall you find it to contain 60 deg.
2. The *Side* *d* E is measured by laying a Ruler to N (the *Pole* of the Circle W Z *d* E) and the point *d*, which Ruler will cut the *Primitive Circle* in ♌, so the distance ♌ E, measured upon a *Scale* of *Chords*, will be found to be 32 deg. 10 min. for the *Side* *d* E.
3. The *Side* M *d*, is measured by laying a Ruler upon *æ* (the *Pole* of the *Circle* M *d* O) and the point *d*, which Ruler will cut the *Primitive Circle* in λ, the distance λ M, measured upon the *Scale* of *Chords*, will give 64 deg. 58 min. for the *Side* *d* M.
4. For the Measure of the *Angle* *d*ME, a Ruler laid from M to *z* (a Quadrant from M) will cut the *Primitive Circle* in P: and the distance P Q measured upon a *Scale* of *Chords*, shall give 36 deg. for the *Angle* *d* ME.
5. For the *Angle* M*d*E, or its *Alternate Angle* *c* *d* O, equal thereunto, lay a Ruler to *æ*, the *Pole* of the *Circle* M *d* O, and upon *d* (the Angular point) it will cut the *Primitive Circle* in λ, Then set 90 deg. from λ to ♈, and lay a Ruler upon *æ* and ♈, it will cut the Circle M *d* O in π; A Ruler laid from *d* (the Angular point) to π, will cut the *Circle* in B, and the distance B W measured upon a *Chord*, will be found to be 72 deg. 54 min. for the quantity of the *Angle* *c* *d* π, equal to the Angle M *d* E.

CHAP.

CHAP. VI.

Of the Sun's Azimuth, *how to find it at any time (the Sun shining)* Geometrically, Instrumentally, *and* Arithmetically

WHat the Sun's *Azimuth* is, you are shewed in the foregoing *Introduction*; Our business here is to find it: This work might have been done by the *Projection* (and that shall be shewed hereafter in its due place) but the *Scheme* being too much incumbred already, I shall shew other ways for finding it. As,

First, *Geometrically*, by help of your Scale of Chords, &c.

Secondly, By the Scale of *Sines* before described: And,

Thirdly, By *Trigonometrical* Calculation.

Before the Sun's *Azimuth* can be found, Three things must be given or known, *Viz.*

1. The *Latitude* of the Place.
2. The *Declination* of the Sun.
3. The Sun's *Altitude:* Which is to be observed by a Quadrant or other Instrument, so often as you have occasion to find the *Azimuth*; But the *Latitude* is alwayes known (or given) and the *Declination* is (nearly) fixed to the time of the *Year*; and for that end, I have in the *Introduction* inserted two *Tables*, the one shewing the *Latitude* of the *Cities*, *Towns*, and *Principal places* in *England*, *Scotland*, and *Ireland*, —— The other of the *Sun's Declination* for every day in the *Year*: The which *Tables* are subservient to the Work of this Chapter.

And now, *Having the* Latitude *of the Place*, *The* Declination *and* Altitude *of the* Sun, *to find the* Azimuth.

I. *Geometrically by* Scale *and* Compass.

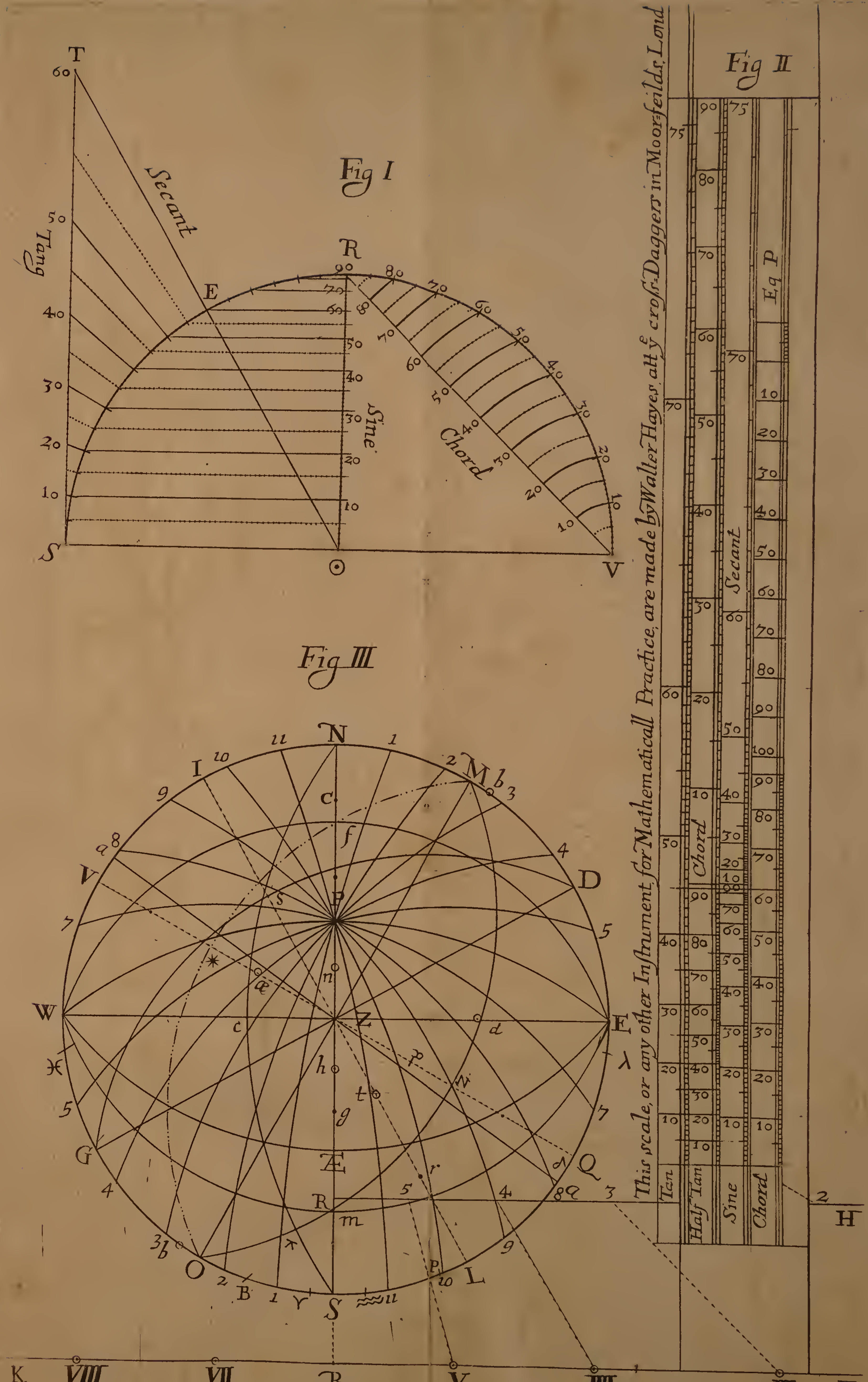
Figure I. HAving the *Latitude* of your Place, and the *Declination* of the Sun, and the Sun's *Altitude* given, you may find the Sun's *Azimuth*. So the Latitude of the Place being 51 deg. 32 min. the Declination of the Sun 17 deg. 56 min. North, and the Sun's Altitude 35 degrees; the *Azimuth* may be found Geometrically as followeth.

First, with 60 deg. of your Line of Chords describe the Semicircle A D C, and upon B the Center, erect the Perpendicular B D.

Secondly, Take 51 deg. 32 min. the Latitude of the Place out of your Line of Chords, set it from D to E, and draw the Line E B, representing the Equinoctial Circle.

Thirdly, Out of your Line of Chords take 17 deg. 56 min. the Sun's Declination, and (because it is Northward) set that distance upwards from E to F, (but if the Declination had been Southward, you must have set it downwards from E to R,) and draw the Line F G parallel to B E, which represents the Sun's parallel for that time.

Fourthly,



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Fourthly, From your Line of Chords take 35 deg. the Sun's *Altitude*, and ſet it from A to H, and from C to L, and draw the Line H K L for the Line of the Sun's Altitude.

Fifthly, Take in your Compaſſes the length of the Line K L, or K H, and with that diſtance, upon the Center B, deſcribe the Semicircle M P N.

Sixthly, Upon the point O (which is where the parallel of the Sun's Declination, and the parallel of the Sun's Altitude, interſect each other) erect the Perpendicular O P.

Seventhly, Lay a Ruler from B to P, and it will cut the Circle in Q, and draw the Line P Q.

Laſtly, Take the diſtance from C to Q, and meaſuring it upon your Line of Chords, you ſhall find it to contain 73 deg. 56 min. and ſo much is the Sun's *Azimuth* or his diſtance from the South part of the Meridian, at the time of Obſervation.

II. *By the Scale of* Sines *upon the Ruler.*

Let the *Latitude*, Sun's *Declination*, and *Altitude*, be the ſame as before, *viz. Lat.* 51 deg. 32 min. *Declination* 17 deg. 56 min. *North*, and the Sun's *Altitude* 35 deg. *Figure* II.

Firſt, With 60 deg. of your Scale of *Chords*, or 90 deg. of the Scale of *Sines*, upon the point $\frac{E}{W}$ deſcribe a Semicircle N B S.

Secondly, Take the Sun's *Declination* 17 deg. 56 min. from your Scale of *Sines*, and ſet it from the point $\frac{E}{W}$, to ⊙ (towards N, the *Declination* being *Northward*, or towards S, if it had been *Southward*).

Thirdly, Find the *Sum* and the *Difference* between the Complement of the *Latitude*, and the Complement of the *Altitude*, the *Sum* of them is 93 deg. 28 min. and the *Difference* is 16 deg. 32 min. and the Complement of the *Difference* is 73 deg. 28 min.

Co. Lat.	38 d.	28 m.
Co. Alt.	55	00
The Sum	93	28
Diff.	16	32
Co. Diff.	73	28

Fourthly, Take 3 deg. 28 min. (the exceſs of the Sum above 90 deg) from your Scale of Sines, and ſet it from the point $\frac{E}{W}$ towards S, namely at A.——Alſo take 73 deg. 28 min. from the Scale of Sines, and ſet that diſtance from the point $\frac{E}{W}$ towards N, at the point D.

Fifthly, Take in your Compaſſes the diſtance between A and D, and ſet it upon the Semicircle from S to B, and draw the Line N B.

Sixthly, Take in your Compaſſes the diſtance between D (the *Difference*) and ⊙ (the point of the Sun's *Declination*) and with that diſtance, ſetting one foot of the Compaſſes upon the Line N S, move it gradually along, till the other foot (being turned about) do only touch the Line N B, and where the foot of the Compaſſes (upon theſe conditions) reſteth, ſet Z; ſo ſhall the diſtance E Z, meaſured upon the Scale of Sines, be found to contain 16 deg. 4 min. And ſuch is the Sun's *Azimuth* from the *East* or *West* points of the Horizon.——Which being taken from 90 deg. leaveth 73 deg. 56 min. for the diſtance Z S, the Sun's *Azimuth* from the *South*.——Or, 90 deg. being added thereto, it

H will

will give the distance Z N, namely, 106 deg. 4 min. and such is the Sun's *Azimuth*, or distance from the *North*.

III. *By Trigonometrical Calculation.*

LEt the *Latitude*, *Declination* and *Altitude* be as before, *viz.*

	d.	m.		d.	m.
Latitude	51	32	Complement	38	28
Declination	17	56	Complement	72	04
Altitude	35	00	Complement	55	00
			Their Sum	165	32
			Half Sum	82	46

The difference between the half Sum and the Complement of the Sun's Declination.——10—42

First, You must add the Complement of the Latitude, the Complement of the Declination, and the Complement of the Sun's Altitude, all three into one Sum, and they make 165 deg. 32 min. the half whereof is 82 deg. 46 min. and the difference between this half Sum 82 deg. 46 min. and the Complement of the Sun's Declination 72 deg. 4 min. is 10 deg. 42 min.

Being thus prepared, the Proportion to find the Sun's *Azimuth* by the Table of Sines, will be as followeth.

(1) As the Radius, or Sine of 90 deg.	10—000000
is to the Sine Complement of the Altitude 55 d.	9—913364
So is the Sine Complement of the Latitude 38 d. 28. m.	9—793832
to the Sine of 30 deg. 38 min.	9—707196
(2) As the Sine of 30 deg. 38 min.	9—707196
is to the Sine of the half Sum 82 d. 46 m.	9—996529
So is the Sine of the difference 10 d. 42 m.	9—268733
	19—265262
to this Sine	9—558066
To which add the Radius, or the Sine of 90 deg.	10—000000
The Sum is	19—558066
Half this Sum is	9—779033

Which is the Sine of 36 d. 58 m. the Complement whereof is 53 d. 2 m. the double whereof is 106 d. 4 m. which is the Sun's *Azimuth*, or distance from the North part of the Meridian: And this 106 d. 4 m. being taken from 108 d. leaveth 73 d. 56 m. for the *Azimuth* from the South

South part of the Meridian. And according to either of these ways you may find the Sun's *Azimuth*, at any time of the day, and in any part of the World.

CHAP. VII

Of the Declination *and* Reclination *of* Plains, *and how to find their quantities.*

WHat a *Declining* and *Reclining Plain* is, we have defined in the foregoing Chapter, we now come to shew how to find the quantity of their *Declination* or *Reclination*.——Now, a *Declining Plain* is best represented by the side *Wall* of a *Church*, *House*, or other upright *Edifice* or *Building*, which doth not directly behold the true *East*, *West*, *North* or *South* points of the *Horizon*: And a *Reclining Plain* is best represented by the Outside of the *Tiling* of the Roof of a Church, House, Coaping of a Wall, *&c.*

Definition 1.] NOW, *The* Reclination *of a* Plain, *Is the quantity of the Arch of that* Vertical Circle, *which passeth through the* Zenith, *and cutteth the* Reclining Plain *at* Right Angles.

Definition 2.] THE Declination *of a* Plain, *is the quantity of that Arch of the* Horizon, *which is comprehended between the true* North *or* South *points, and a Line drawn* Perpendicular *to the* Plain. *Or,*

It is the quantity of that Arch *of the* Horizon, *which is intercepted between the true* East *or* West *points, and the* Plain *it self.*

I. *How to find the* Reclination *of a* Plain.

Practice. LET A B C D being the Roof of the Building P L R X, represent a *Reclining Plain.* First, Draw thereon an *Horizontal Line* as EF, which you may do by help of an ordinary Level, or by applying a *Ruler* to the *Plain*, and letting One hold the Ruler so to the *Plain*, till you find, by the edge of a *Quadrant* applied to the *Ruler*, the *Line* and *Plummet* to fall just upon the edge thereof, as in the *Figure*: Then draw a Line by the side of the *Ruler*, as E F, and that shall be the *Horizontal Line* of the *Reclining Plain* A B C D. *Figure* III.

To this *Horizontal Line* E F, draw another, Line *Square* (or at Right Angles) thereunto, as the Line G H; to which Line apply the side of a *Ruler* M N, and towards that end which hangeth over the *Plain* as at N, apply the side of a *Quadrant*, letting the *Plummet* hang at free liberty, to play by the side of the *Quadrant*, and when it resteth, note what degrees of the *Quadrant* the Thread falleth upon, for those *degrees* are the quantity of the *Plain's Reclination.*

To

II. *To find the* Declination *of a* Plain.

Figure III.

IN taking the *Declination* of a *Plain*, Two *Observations* are to be made by the *Sun*, both which ought to be done at the same moment of time, or as neer together as may be; The First, is to find the *Horizontal distance* of the Sun from the *Pole* of the *Plain*: And is called the *Horizontal Distance*. The other is the Sun's *Altitude*, thereby to find his *Azimuth*.

1. *For the* Horizontal Distance.

Let PQRS be an *Upright Plain*, whose *Declination* is required: First, By help of a *Level*, or by your *Quadrant*, draw an *Horizontal Line* upon the *Plain*, as the Line TV, unto which apply one side of a *Quadrant*, so that the *Limb* of the *Quadrant* may be towards the *Sun*; Then holding a *Thread* and *Plummet* at full liberty by the *Limb's side*, so that the *shadow* of the *Thread* may pass, both through the *Center* and the *Limb* of the *Quadrant*: And observe then what number of Degrees are cut off by the *shadow* of the *Thread*, and number them from that side of the Quadrant that standeth square (or *Perpendicular*) to the Plain; for those *Degrees* are the *Horizontal Distance* required.

2. *For the Sun's* Altitude.

At the same instant of time that you observed the *Horizontal Distance*, the *Sun's Altitude* should have been observed also, which could not be done but by two Observers; wherefore, let them be observed as neer together as may be.

To take the *Altitude* of the *Sun*, you must take the *Quadrant* in both your hands, laying your right hand somewhat neer that side that hath the Sights, and your left hand towards the other side, by which means you may let it slip lower, or raise it higher, as occasion requires: Then turning the left side of your body to the Sun, move the *Quadrant* up or down, till the Sun shining through that *Sight* which is next the *Center* of the *Quadrant*, do cast his *Ray* or *Beam of Light* upon the *hole* of the other *Sight*, (the *Thread* and *Plummet* (all this while) hanging at free liberty) and then look in the *Limb* of the *Quadrant* what *Degrees* and parts of a *degree*, the *Thread* cutteth; for those degrees are the *degrees* of the *Sun's Altitude* at that time.

¶ By help of the Sun's *Altitude*, the Sun's *Azimuth* may be found. ——Then by comparing the *Sun's Azimuth* and the *Horizontal Distance* (before found) together, the *Plain's Declination* may be obtained, by the *Rules* following.

When you make your *Observation* of the Sun's *Horizontal Distance* from the *Perpendicular* of the Plain, Mark whether the *Shadow* of the *Thread*

Thread do fall between the *South* Point of the *Horizon*, and that ſide of the *Quadrant* which is Perpendicular to the Plain. For,

Rule I. If the *Shadow* fall between them, then the *Horizontal Diſtance* and *Azimuth* added together, do make the *Declination* of the *Plain*: And (in this *Caſe*) the *Declination* of the *Plain* is towards the ſame Coaſt whereon the Sun's *Azimuth* is: That is,

¶ If the *Obſervation* be made in the *Forenoon*, when the Sun is *Eaſtward* of the *Meridian*, the *Plain* Declineth *Eaſtward*:——But if the *Obſervation* be made in the *Afternoon*, when the Sun is *Weſtward* of the Meridian, The Plain Declineth *Weſterly*.

Rule II. If the *Shadow* fall not between the *South* Point, and that ſide of the *Quadrant* which is *Perpendicular* to the *Plain*, then the *Difference* between the Sun's *Azimuth* and the *Horizontal Diſtance* is the *Declination* of the *Plain*: And if the *Azimuth* be the *Greater* of the two, then the *Plain* Declineth to the ſame *Coaſt* whereon the Sun is. That is,

¶ It Declineth *Eaſtward* if it be in the *Forenoon*, or *Weſtward* if in the *Afternoon*.

But if the *Azimuth* be *Leſſer* than the *Horizontal Diſtance*, then the *Plain declineth* to the Coaſt contrary to that the Sun is on. That is,

¶ The *Plain declineth Weſt*, if the *Obſervation* be made in the *Forenoon*: But *Eaſt* if in the *Afternoon*.

¶ *And here it is to be further* Noted, *That the* Declination *of any* Plain *found by theſe* Rules, *is always accounted from the* South; *And that all* Declinations *are accounted from the* North *or* South *towards the* Eaſt *or* Weſt, *and muſt never exceed* 90 *degrees*.

Therefore,

1. If the number of degrees of *Declination*, do exceed 90, you muſt ſubſtract it from 180, and the reſidue ſhall be the *Declination* of the *Plain* from the *North*.

2. If the number of degrees of *Declination* do exceed 180, then the number of degrees above 180, gives the *Plain's Declination* from the *North*, and it is towards that Coaſt (either *Eaſt* or *Weſt*) which is *contrary* to the *Coaſt* upon which the *Sun* was at the time of *Obſervation*.

For the farther Explanation of theſe Rules (Examples being more ſatisfactory than bare Precepts) I ſhall here inſert two Obſervations made upon two ſeveral Plains at the ſame time, *viz.*

Upon the 23d of *Auguſt* in the *Morning*, I came to the *Plain* PQRS, and applying my *Quadrant* thereto, and holding up a Thread and Plummet by the ſide thereof, I found the *Horizontal Diſtance* to be 61 deg. equal to the Angle *bac* in the Quadrant.——At the ſame time (as near as I could) I went to the other *Plain* KLOX, and thereto I applied *Figure* III.

 my

my *Quadrant*, as in the Figure, and found the *Horizontal Distance* to be 17 deg. In the mean time that I was taking the two *Horizontal Distances*, an Assistant observed the Sun's *Altitude*, from whence I computed the Sun's *Azimuth*, and found the *Azimuth* to be 68 deg. *Easterly* of the *South*.

Having these *Notes* of *Observations*, I compute the *Declinations* as followeth:

Figure IV. First, For the *Plain* PQRS. Upon a piece of Paper with 60 deg. of a *Scale of Chords*, describe upon the Center *o*, a Semicircle, *a c b*, and because the *Horizontal distance* was 61 deg. set 61 deg. upon the *Semicircle* (the same way you observed the Sun to be) from *c* to *d*, and draw the Line *o* ⊙, for the Line of the Sun's *Azimuth*. Then the Sun's *Azimuth* being 68 deg. Eastward of the *South*, take 68 deg. and set them from *d* Southwards to S, and draw the Line *o* S, for the *Meridian Line*. By your *Scheme* you see that the Line of *Shadow*, *o d* ⊙, does not fall between S (the *South* point) and *o c* (the side of the *Quadrant* which was Perpendicular to the Plain) therefore, by the *Second Rule*, The *difference* between the *Sun's Azimuth* and the *Horizontal Distance*, must be the *Declination of the Plain:* Wherefore *substract* 61 the *Hor. dist.* from 68 the *Azimuth*; the *difference* is 7 deg. which is the *Plain's Declination.* And by the same *Second Rule*, because the *Azimuth* was *greater* than the *distance*; the *Plain declines* to the *same Coast* on which the *Sun* was, namely, *Eastward*, it being *before Noon.* And so it doth appear by the *Scheme*, for 22 deg. (the Complement of 68 deg. the *Azimuth* from the South) being set *Eastward* from *d*, will give E the *East* Point, and the Line *o* E, will be the *East* and *West* Line: So that by your Scheme also you may see that the Plain lies open to the *South* and the *East*, and the Quantity of *Declination* is the Arch S *c*, or E *b*, either of which are 7 deg.

Figure V. Secondly, For the Plain KLOX. Upon a piece of Paper with 60 deg. of the *Scale* of *Chords*, upon *r* as a Center, describe a *Semicircle*, *m p n*, and because the *Horizontal distance* was 17 deg. set 17 deg. upon the *Semicircle* as you found it to be by Observation, from *p* to *h*, drawing the Line *r* ⊙ for the Line of the *Sun's Azimuth*, then the *Azimuth* being 68 deg. from the *South Easterly*, set 68 deg. *Southerly* from *h* to S, and draw *r* S for the *Meridian Line*, and set 22 deg. (the Complement of the Sun's *Azimuth* to 90) from *h* towards the *East*, at E, and draw the Line *r* E for the *Azimuth* of *East*. Now by the *Scheme* you see, that the Line of *Shadow* falls between the *South point* and *r p*, the side of the *Quadrant*, which was *Perpendicular* to the *Plain*; therefore, by the *First Rule*, the *Horizontal distance* and *Azimuth added* together, do make the *Declination* of the *Plain*: Wherefore 68 the *Azimuth* and 17 the *Horizontal distance*, added, do make 85 deg. for the *Declination of the Plain*; and by the same *first Rule*, the *Declination is Easterly*, it being towards the *same Coast* that the Sun was on: And so it appears to do by your *Scheme* also, the Plain beholding the *South* and the *East*, The *North* and *West* falling behind the Plain. And thus have you several ways to find the Sun's Azimuth, and consequently a *Meridian Line.* But before I conclude this Chapter, I will shew you an exact and accurate way.

How

How to find a true *Meridian Line*, in any *Latitude*, without knowing the *Sun's Declination*, or finding of his *Azimuth*: By help of three *Shadows* caſt by a *Gnomon* erected upon an *Horizontal Plain*; and three *Altitudes* of the Sun taken at the ſame times.

In ſome convenient Place upon an *Horizontal Plain* (unto which the Sun may have free acceſs) erect a *Gnomon* (or wyre) of convenient length, Perpendicular (or at Right Angles) to the *Plain*.

The *Plain* thus prepared; At any three times in the ſame day, mark upon the *Plain* where the *Shadows* of the *Gnomon* caſteth; And at the ſame three times, take three ſeveral *Altitudes* of the Sun; which ſet down upon each *Shadow*.

Then through the three *Shadows*, from the foot of the *Gnomon*, draw three Right Lines of ſufficient length: And, from your Scale of *Half-Tangents*, take the Complements of the Sun's *Altitudes* (as you found them to be, at the times you obſerved the *Shadows*) and ſet them upon their reſpective lines of *Shadow*, from the foot of the *Gnomon*: So ſhall you have three Points upon your Plain, through which (by the XI *Probl.* of the *Introduction*) deſcribe a Circle.

Laſtly, A Right Line drawn through the Center of this Circle, and the foot of the *Gnomon*, ſhall be a true *Meridian Line*.

Note, *It matters not whether theſe three Obſervations be made all of them before or after Noon; or ſome before and others after Noon.*

CHAP. VIII.

How to know which of the Poles, *whether the* North *or* South *is to be* Elevated *above any* Dial-Plain; *whether* Direct *or* Reclining, *or both* Reclining *and* Declining.

THE *Axis* or *Stile* of every *Dial* lies Parallel to the *Axis* of the *World*, and therefore the two ends of the *Stile* of every *Dial* do directly reſpect the two *Poles* of the *World*: And therefore if the *South Pole* be elevated upon any *Dial Plain*, a *Dial* made on the backſide of that *Plain*, will have the *North Pole* Elevated: And hereafter, that no doubt may ariſe concerning which *Pole* muſt be Elevated above any *Plain*; take theſe few

General Rules.

1. Upon the *Horizontal Plain*, in *North Latitude* the *North Pole*, but in *South Latitude* the *South Pole* is Elevated.

2. Upon all *Erect Plains*, whether *Direct* or *Declining*: If the *Plain* lie open to the *South*, the *South Pole* is Elevated; but if it behold the *North*, the *North Pole* muſt be Elevated.

3. Upon all Direct *East* or *West Plains*, *Reclining* (how far soever) the *North Pole* is Elevated; and upon the *East* and *West Incliners*, opposite to them, the *South Pole*.

4. Over all *North Reclining Plains*, (whether *Direct* or *Declining*) the *North Pole* is Elevated; and over the *Inclining Plains*, opposite to them, the *South Pole*.

Lastly, Over all *South Reclining Plains*, whether *Direct* or *Declining* [*If the Plain pass between the* Zenith *and the* Pole] the *Axis* of the *Stile* must have respect to the *South Pole*; and on the *Inclining Plains*, opposite to them, the *North Pole*.——But, [*If the Plain pass between the* Horizon *and the* Pole] the *North Pole*; and on the *Incliners* opposite to them, the *South Pole*.

CHAP. IX.

To Draw the Hour Lines *upon a* Vertical (*commonly called* Horizontal) Plain.

I. *From the* Projection.

Figure I. FIrst, Draw a right Line NS, for the Meridian, and Hour-Line of 12, and cross it with another E W, for the Hour-Line of Six, at right Angles in Z; And upon Z, as a Center describe a Circle E N W S, representing the *Horizon* of *London*, whose *Latitude* is 51 d. 32 m. and also this *Dial-Plain*. Within this Circle *Project* the *Sphere* according to your Latitude, as is before taught, then shall the several *Hour-Circles* touching the *Plain* of the *Horizon*, give you Points to draw the Hour-Lines upon your Dial-Plain by: So that a *Ruler* laid to Z, and every of the Points 1, 2, 3, *&c.* 11. 10. 9, *&c.* Where the *Hour Circles* touch the *Horizon*, if you draw straight Lines thereby, they shall be the true Hour-Lines for your *Vertical* (or *Horizontal*) *Dial*.

For the making of an *Horizontal Dial*, there is nothing required to be known, but the Latitude of the Place, equal to which must the height of the Stile be; wherefore take 51 deg. 32 min. out of your Scale of Chords, and set them upon the *Horizon* from S to A, and draw a Line Z A for the *Stile*. The *Substile* (upon which the *Stile* standeth) in all *Horizontal Dials* is the *Meridian* or Hour Line of 12; and so is the *Dial* finished.

II. *By* Trigonometrical *Calculation*.

There is nothing required to be found in this Dial by Calculation, excepting the *Hour-Distances* from the *Meridian*; for which this is the Proportion.

As the Sine of 90 deg.
Is to the Sine of the Latitude.
So is the Tangent of each Hour's Equinoctial Distance from the Merid.
To the Tangent of that Hour's Distance upon the Plain.

Where

Fig. I.

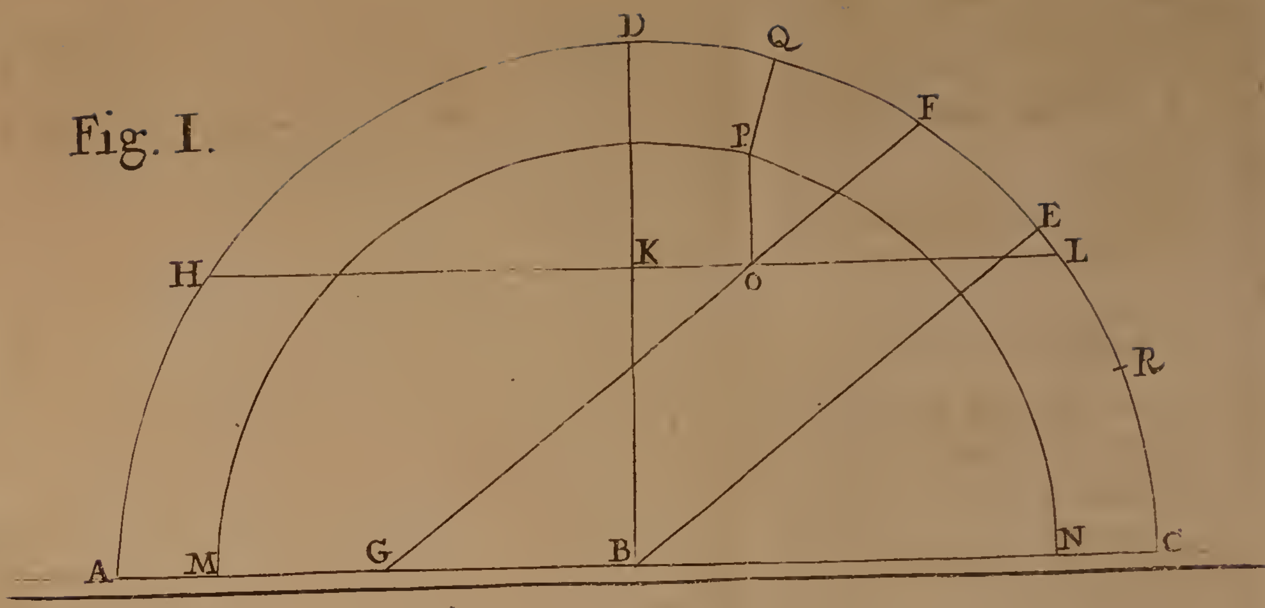

Fig. II.

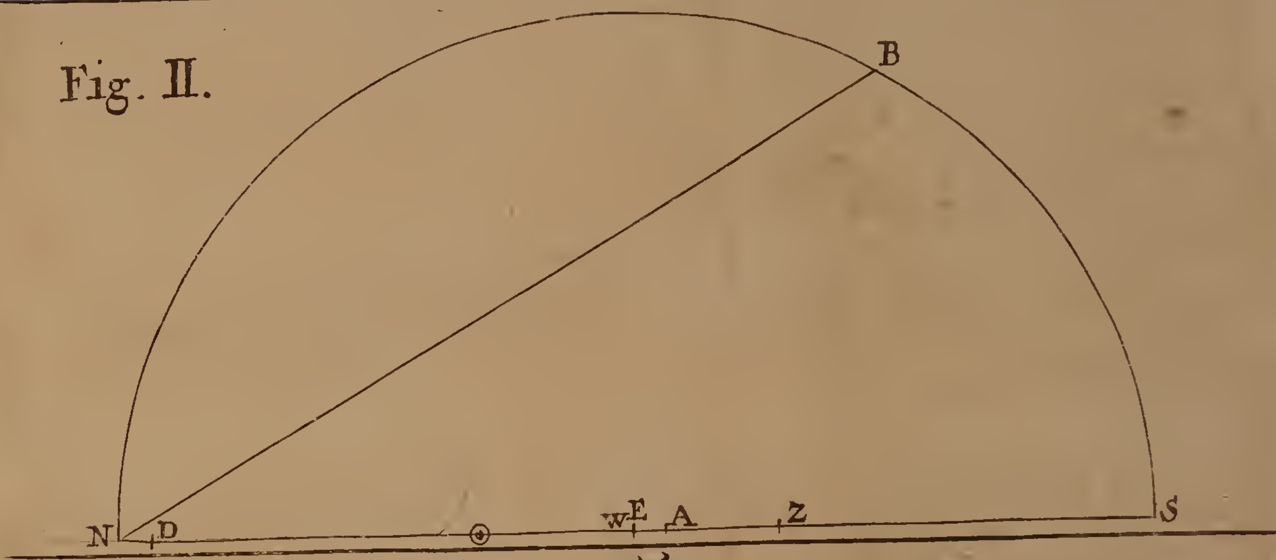

Fig. III.

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Page 32.
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Wherefore, having prepared a Table, and placed the Hours from Noon in the *First Column*, and the *Equinoctial Distances* proper to them in the *Second Column* (allowing 15 deg. to one Hour, 30 deg. to 2 Hours, *&c.*) as you see here done, then work your Proportion as followeth.

As the Radius 90 deg.	10.000000
To Sine of the Latitude 51 deg. 32 min.	9.893544
So the Tang. of 15 deg. the first Hour's Equi. Distance.	9.428052
To Tang. of 11° 51′ the first Ho. Dist. on the Plain,	9.321596

Hours from Noon.		Equinoctial Distances. D.	M.	Hour Distances on the Plain. D.	M.
12		0	0	0	00
11	1	15	0	11	51
10	2	30	0	24	19
9	3	45	0	38	3
8	4	60	0	53	36
7	5	75	0	71	6
6		90	0	90	0

And doing thus for every Hour's Equinoctial Distance, you shall produce such Hour-Distances as you find in the third Column of the Table. Which Distances being taken out of a Line of Chords, and set upon the Plain from S, will give the Points 1, 2, 3, *&c.* 11, 10, 9, *&c.* as before; for between S and 11 or 1, you shall find 11 deg. 51 min. from S to 10 or 2, 24 deg. 19 min. *&c.*

And thus have you two ways, *viz.* A *Geometrical* or *Projective* way, and an *Arithmetical* or *Calculatory* way to make your *Dial*, demonstrating one another. And in this order I shall proceed in all other Plains.

CHAP. X.

How to Describe the Hour-Lines *upon an Erect Direct* South *or* North Plain.

I. *By the* Projection.

HAving drawn a right Line N S for the *Meridian* or Line of 12, and another at right Angles thereto, as E W for the *Horizontal* Line of the Plain, crossing each other in the point Z. Upon Z as a Center, describe a Circle N E S W, representing the *Horizon* of *London*, and therein *Project* the *Sphere*. Which done, your next work will be, to draw a line upon your *Projection*, which shall represent your Plain, [*And here Note, That all upright Plains are represented upon the* Projection *by streight Lines.*] Now an Erect Direct Plain, which beholdeth the *South*, must needs lie in the *Azimuth Circle* of *East* and *West*; therefore, a right Line drawn from E to W, shall represent your Plain. *Figure* II.

Having drawn your *Plain* upon the *Projection*, your first work will be to find the *Pole* thereof: And here you are to Note, That [*The* Pole *of every Direct Plain, whether* Erect *or* Reclining, *is removed* 90 *deg. from the Plain it self; and that every Plain hath two Poles, and a Line being drawn from one to the other, will cut the Plain at Right Angles.*] Now this Plain E W, lying in the Azimuth of East and West, the Poles thereof must lie in the Azimuth of North and South; so that N is the Pole of the North face of this Plain, and S of the South Face, either of which Poles are removed 90 deg. from the Plain; and a Line drawn from one *Pole* to the other, will cut the *Plain* at Right Angles in Z.

The next thing to be found is the Elevation of the Pole of the World above the Plain. Now [*The Elevation of the Pole above all direct Plains, is an Arch of the Meridian intercepted between the Pole and the Plain, and never exceedeth* 90 *deg.*] Now P, the Pole of the World, is elevated above this Plain E W, the quantity of the Arch of the Meridian ZP. To find the quantity whereof, Take the distance Z P in your Compasses, and measure it upon your Scale of *Half Tangents*, and you shall find it to contain 38 deg. 28 min. equal to the Complement of the Latitude, and so it ought to be.——Or, if you have not a Scale of *Half Tangents*, you may find it thus: Lay a Ruler to E and P, it will cut the Circle in *a*, the distance between W and *a*, measured upon the *Chords*, will be found 38 deg. 28 min. as before.

The Third thing to be found is the Hour-distances upon the Plain: To do which,

Lay a Ruler to N (the Pole of the Plain) and to the several Points 1, 2, 3, *&c.* 11, 10, 9, *&c.* where the hour-Circles of the *Projection* do cut the *Plain*, and where the Ruler cuts the Primitive Circle, make small marks, or ***, So Lines drawn from the Center Z, through those marks or ***, shall be the true *Hour-lines* upon your Dial Plain.

The height of the Pole above the Plain being found to be 38 d. 28 m. take those degrees from a Scale of Chords, and set them from S to B, and draw a Line Z B for the *Stile*, which must stand upon the *Meridian*, and on the South face must point downwards to the *South Pole*, and on the North face upwards to the *North Pole*; as in Fig. II, III.

II. *By* Trigonometrical *Calculation.*

There is no more of Calculation in this Dial, than there was in the Horizontal, namely the Hour-distances upon the Plain: For in these direct North and South Dials, the Complement of the Latitude is evermore the height of the Pole above the Plain, as appears by the Projection: Wherefore, prepare a Table (as in the former Dial) and then the Analogie or Proportion for the Hour-distances will be this, little differing from the former, only instead of Latitude, use Co-Latitude. So.

Hours from Noon.		Equinoctial Distances. D.	M.	Hour-Distances on the Plain. D.	M.
12		0	0	0	00
11	1	15	0	9	28
10	2	30	0	19	45
9	3	45	0	31	53
8	4	60	0	47	8
7	5	75	0	66	42
6		90	0	90	0

As

As the Radius, 90 deg.	10.00000
To the Co-Sine of the Latitude (or heighth of the Pole above the Plain) 38 deg. 28 min.	9.79383
So is the Tang. of 15 d. the first Hour's Equ. dist.	9.42805
To 9 d. 28 m. the first Hour's distance upon the Plain.	9.22188

For the North Dial.

1. Upon the Dial Plain, draw an obscure down-right Line N S, representing the *Meridian*, or 12 a Clock at Midnight.— About the middle thereof, as at Z, draw a right Line perpendicular thereunto, as the Line E Z W for the Hour-line of VI. *Figure* III.

2. With 60 deg of your Chord describe upon the Center Z, the Circle E N W S, and taking 38 deg. 30 min. out of the Line of Chords, set them from N to A, and draw the Line Z A for the *Stile* of your Dial.

Now because this Dial looketh towards the *North* part of the *Meridian*, to which in these middle Latitudes without the *Tropicks*, the *Sun* never cometh, therefore must the Hours about Midnight be omitted, as 9, 10, 11 and 12 at Night, and 1, 2 and 3 in the Morning; So that this *Dial* is capable only of the Hours of 4, 5, 6, 7, and 8 in the Morning, and of 4, 5, 6, 7, and 8 in the Evening.

3. Lay the former Table made for the *South Dial* before you, and there you shall find the Hour-distances of VIII and IV of the Clock, are distant from the *Meridian* 47 deg. 8 min. Take 47 deg. 8 min. from your Chord, and set them from N to 8, and from N to 4, aud also from S to 8, and from S to 4. Also seeing that the Hour-distances of VII and V are different from the *Meridian* 66 deg. 42 min. take them also out of your Line of Chords, and set them from N to 7, and from N to 5, and also from S to 7, and from S to 5.

Lastly, The *Stile* of the Dial must make an Angle of 38 deg. 28 min. equal to the Complement of the Latitude, and must stand upon the obscure Hour-line of 12 at Night, and must point upwards towards the *North Pole*, as the *South Dials* did downwards towards the *South Pole*. And so have you finished your Dial.

CHAP. XI.

To describe Hour Lines, *upon an* Erect Direct East *or* West Plain.

AS an Erect Direct *North* or *South Plain*, lies in the Azimuth Circle of *East* and *West*, and is represented upon the *Projection* by the Line E W, *Fig.* II. the Poles whereof were N and S; So an Erect Direct *East* or *West Plain*, lies in the Azimuth Circle of *North* and *South*; and so the Plain is represented upon the *Projection* by the Line N S; and the *Poles* of those Plains are E and W.

Now

Now the Line N S, repreſenting the Plain, paſſeth directly through P, the Pole of the World; and therefore the *Pole* hath no Elevation above theſe *Plains*, and conſequently the *Dial* will have no *Center*, but all the Hour-Lines will be *Parallel* one to the other: and theſe *Dials* may be drawn according to theſe following Directions.

The Geometrical Conſtruction of theſe Dials.

Figures IV. V. Let A B C D be a Dial Plain, upon which you would draw an *Eaſt* or *Weſt* Direct Dial.

1. Upon the point C, at one lowermoſt corner, if it be an *Eaſt* Dial; or upon the point D at the other lowermoſt corner, if it be a *Weſt* Dial, with 60 deg. of your Line of Chords, deſcribe an obſcure Arch of a Circle E F: Then from the ſame Line of Chords, take 38 deg. 28 min. the Complement of the Latitude of the Place (which is alſo the Elevation of the Equinoctial above the Horizon) and ſet that diſtance upon the Arch from E to F, and draw the Line C F quite through the Plain, which Line ſhall repreſent the Equinoctial Circle.

2. That you may the better proportion your Stile to your Plain, and that all the Hours may come on, and be at a convenient diſtance one from another, aſſume two points in the Equinoctial Line, one towards the end C, for the Hour of 11 in the *Eaſt* Dial (or of 1 in the *Weſt* Dial) as the point G, and another towards the other end thereof, for the Hour of 6, as the point H; and through theſe two points G and H, draw two Lines at right Angles to the Equinoctial Line, for the Hour-Lines of XI and VI a Clock.

3. Upon the point G with 60 deg of the Line of Chords deſcribe an obſcure Arch of a Circle (below the Equinoctial Line) as I K, ſetting thereon 15 deg. of your Line of Chords, from I to K, and draw the obſcure Line G K, extending it till it cut the Hour-Line of VI in the point L; ſo ſhall the diſtance L H be the heighth of the perpendicular Stile, proportioned to this Plain.

4. Open your Compaſſes to 60 d. of your Line of Chords, and ſetting one foot in the point L; with the other deſcribe an obſcure Arch of a Circle M N; between the Hour-Line of VI and the Line G L.

5. Divide the Arch M N into five equal parts (which 15 d. of your Line of Chords will do) at the points ⊙⊙⊙⊙⊙, and lay a Ruler from L, to each of theſe points ⊙⊙⊙⊙⊙, and the Ruler ſhall cut the Equinoctial Line C H in the points ****, through which points draw right Lines parallel to the Hour-line of VI, as the Lines VII * VII, VIII * VIII, IX * IX, X * X, and they ſhall be the true Hour-lines of an Eaſt Plain, from Six in the Morning to Eleven before Noon.

6. For the Hour-lines before VI, namely of IV and V in the Morning, you may put them on by tranſferring the ſame Diſtances upon the Equinoctial line before VI, as there is between VI, and the Hour-lines of VII and VIII after VI, and through thoſe points draw Lines parallel to the Hour-line of VI, and they ſhall be the Hour-lines of IV and V in the Morning.

7. For the Stile of theſe Eaſt or Weſt Dials, it may be either a ſtreight Pin or Wire pointed, of the juſt length of the line H L, fixed in the point H, or ſome other part of the line of VI, perpendicularly to the Plain, which will ſhew the true hour only by the ſhadow of the very top

top thereof, as in the Weſt Dial, Figure V.——Or, (which is better) it may be a Plate of Braſs or Iron, of the ſame breadth as is the diſtance between the Hour-lines of VI and IX upon the Equinoctial, as in the Eaſt Dial, Figure IV; which Plate muſt be ſet perpendicularly upon the Hour-line of VI, which ſhall ſhew the Hour by the ſhadow of the upper edge thereof: and ſo is your Dial finiſhed.

8. If you would inſert the halves and quarters of hours into theſe Dials, you may eaſily effect it, by dividing each ſpace between ⊙ and ⊙ on the Arch M N, into four equal parts and ſo transferring them to the Equinoctial Circle, as you did the whole hours. All which may be plainly ſeen in Figure V.

In the making of this Dial you have made two Dials, namely a Weſt Dial as well as an Eaſt, for it is the ſame in all reſpects as to the Hour-diſtances and height of the Stile.——Only whereas the Arch E F in the Eaſt Dial (through which the Equinoctial paſſeth) was deſcribed on the Right-hand of the Plain, upon the Center C: In the Weſt Dial it muſt be deſcribed on the Left-hand, upon the Center D: And the Hour-lines of IV, V, VI, VII, VIII, IX, X, and XI in the Forenoon, on the Eaſt Dial; muſt be VIII, VII, VI, V, IV, III, II, and I in the Afternoon, on the Weſt-Dial: as the Figures IV and V do evidence.

CHAP. XII.

How to draw the Hour-Lines upon an Erect North *or* South *Plain* declining Eaſt *or* Weſt.

I. *By* Projection.

OUR Example ſhall be of an Upright Plain, declining from the South Weſtward 30 degrees. *Figure* VI.

Firſt, Draw a Right-line A B, repreſenting your Declining Plain, croſſing it with another Right-line C D, at Right Angles in Z, making Z for the *Zenith* of the *Place*, and Center of your Dial; and upon Z deſcribe a Circle A B C D,—— Then from C, towards B (becauſe the Plain declineth Weſtward, or from C towards A, if it had declined Eaſtward) ſet 30 deg. the *Declination of your Plain*, from C to N, and draw the Line N Z S, for the *Meridian of the Place*, upon which, from Z to P ſet off the Pole of the World, and finiſh your *Projection* as is before taught.

Secondly, Your *Projection* being finiſhed, A B being the Line repreſenting the Plain, the points C and D are the Poles thereof, they being 90 deg. diſtant from A and B.—— And now you have three points given, namely, C, P and D, through which three points (by the 11th. Problem of the *Introduction*, draw an Arch of the Circle C P R D, whoſe Center will always fall in the Line of the Plain A B, it being extended: This Circle is an Arch of a *Meridian* or *Hour-Circle*, paſſing through P the *Pole of the World*, and C and D the *Poles of the Plain*, and cutteth the Plain A B at Right Angles in R, and is therefore called the *Meridian of the Plain*. The *Pole* of this Circle muſt next

be found, and that may be done in this manner. Lay a Ruler from D to R, it will cut the Primitive Circle in *a*, then take always 90 deg. of your Chord (becauſe, the *Poles of all Great Circles of the Sphere are* 90 deg. *diſtant from the Circles themſelves*) and ſet them from *a* to *e*, and if you lay a Ruler from D to *e*, it will cut the Line of the *Plain* in Q, ſo is Q the *Pole of the Circle* C R D.

Thirdly, The Sphere being projected, and the Lines and Circles relating to this Plain drawn upon the *Projection*: There are Three things to be found before you can draw the Hour-lines: And thoſe three things are all compriſed in the little *Spherical Triangle* P Z R: The three things to be found, are

1. *The Height of the Pole above the Plain*, Repreſented in the *Triangle* by the ſide P R, the quantity whereof may thus be found. —— Lay a Ruler upon Q (the Pole of the Circle C R D) and P, the Pole of the World, it will cut the Circle in *h*, and the Arch B *h* meaſured upon a Scale of Chords, will be found to be 32 deg. 36 min. and ſo much is the Pole of the World elevated above the Plain A B.
2. The ſecond thing to be found, is the *Deflection*, or the *Subſtile's diſtance from the Meridian of the Place*; repreſented in the Triangle by the ſide Z R, and may thus be found.——— Lay a Ruler upon D, the Pole of the Plain A B, and R; it will cut the Circle in *a*; the diſtance *a* C meaſured upon the Chords will give 21 deg. 40 min. for the ſide Z R, which is the *Subſtile's diſtance from the Meridian:* Or, The Line Z R meaſured upon the Scale of *Half Tangents*, will give 21 deg 40 min. alſo.
3. The third thing to be found is, *The Plain's difference of Longitude:* Or, *The Angle between the Meridian of the Place* N Z S, *and the Meridian of the Plain* C R D, and is repreſented in the Triangle by the Angle Z P R: the quantity whereof may be thus found.—— Lay a Ruler upon P, the Pole of the World, and V, the Point where the Circle C R D croſſeth the Equinoctial, and it will cut the *Primitive Circle* in *k*, the diſtance S *k* meaſured on a Scale of Chords, will give 35 deg. 26 min. for the Plain's Difference of Longitude.

And now for the drawing of the Hour-lines; Lay a Ruler to C, and to the ſeveral Points 9, 10, 11, and 1, 2, 3, 4, &c. where the *Hour-Circles* croſs the Line of the Plain A B, and where the Ruler croſſeth the Primitive Circle, make ſmall marks or * * *, and Lines drawn from the Center Z, through thoſe marks or * * *, ſhall be the true *Hour-Lines* belonging to the Declining Plain.

A Ruler laid from C to R, will give the Point L, whereby to draw the *Subſtilar Line* Z L; and 32 deg. 36 min. ſet from L to F, will give the Point whereby to draw the *Stile* Z F. And ſo is your Dial Finiſhed.

From this South Plain declining Weſt, a South Dial is alſo made declining Eaſt 30 deg. turning from the Eaſt ſide to the Weſt ſide, and the contrary: and by changing the names of the Hours, by calling 11 One, 10 Two, 9 Three, &c. alſo 1 Eleven, 2 Ten, &c. the Forenoon-Hours in the Weſt Dial, being the Afternoon-Hours in the Eaſt, and the contrary: An Example of a North Dial declining Eaſtward 45 deg. you have in Figure VII.

II. By

II. *By* Trigonometrical *Calculation.*

Before you can draw the Dial, you are to find out the three fore-mention'd *Requisites*, viz. (1.) *The height of the Pole above the Plain.* (2.) *The Deflection*, or *Substile's distance from the Meridian.* (3.) *The Plain's difference of Longitude*: All which are parts of the Spherical Triangle P R Z, right Angled at R:——In which there is given, (1.) The side P Z 38 deg. 28 min. equal to the Complement of the Latitude of the Place. (2.) The Angle P Z R, the *Complement* of the *Plain's Declination* 60 deg. (3.) The Right Angle at R. And by these *Three* things given, you may find.

I. *The Height of the Pole or Stile above the Plain.*

As the Sine of 90 deg.——————10.00000

Is to the Sine Complement of the Lat. 38 deg. 28 min.——9.79383 cos La
So is the Sine Complement of the Plain's Declin. 60 deg.——9.93753 cos 30

To the Sine of 32 deg. 36 min. 9.73136

Which 32 deg. 36 min. is the height of the Pole or Stile, above the Plain.

II. *The Distance of the Substile from the Meridian.*

As the Sine of 90 deg.——————10.00000

Is to the Sine of the Plain's Declination 30 deg.——————9.69897
So is the Tangent of the Complement of the Latitude of the Place 38 d. 28 m.——————9.90008 Cot. La

To the Tangent of 21 deg. 40 min.——————9.59905

Which 21 deg. 40 min. is the distance of the Substile from the Meridian.

III. *The* Plain's *Difference of Longitude.*

As the Sine Complement of the Latitude 38 deg. 28 min.——9.79383 cos Lat

Is to the Sine of 90 deg.——————10.00000
So is the Sine of the Substile's distance from the Meridian 21 deg. 40 min.——————9.56736

To the Sine of 36 deg. 25 min.——————9.77353

Which 36 deg. 25 min. is the Plain's difference of Longitude.

From

From the Plain's difference of Longitude thus found, allowing 15 deg. of the Equinoctial for one Hour, and one Degree for four minutes of time, it will follow, that the Substile of the Dial (which is the Meridian of the Plain) must fall between the Hour-Lines of 2 and 3 of the Clock in the Afternoon, because the Plain declineth Westward: For the Plain's difference of Longitude falling between 30 and 45 deg. (namely between the second and third Hour's Equinoctial distance) there will be two compleat Hours, and 6 deg. 25 min. more. Wherefore, make a Table of the Hours fit for the Plain, as is here represented to the Eye: In which, against the Hour of XII, set the Plain's difference of Longitude 36 deg. 25 min. from which substract 15 deg. and there will remain 21 deg. 25 min. which set against the Hour of XI and I, and from 21 deg. 25 min. substract 15 deg. and there will remain 6 deg 25 min. which set against the Hour of X and II; and (because it is less than 15 deg.) write the word *Substile*, and substract 6 deg. 25 min. from 15 deg. then will there remain 8 deg. 35 min. which set above the word *Substile*, against the hours of IX and III, which, by the continual addition of 15 deg. will give you the Equinoctial Hour-distances of each Hour, as in the Table. Which Table being made, the next thing will be

A Table of the Hour-distances of a South Dial declining either to the East or West, 30 deg. 00 min.

Latitude of the Place	51 d.	32 m.
Dist. of Substile and Merid.	21	40
Height of the Stile	32	36
Plain's differ. of Longitude	36	25

Hours for the East	Hours for the West	Hour-distances at the Equinoctial D.	M.	True Hour-distances on the Plain D.	M.
V	VII	68	35	53	57
VI	VI	53	35	36	08
VII	V	38	35	23	16
VIII	IV	23	35	13	14
IX	III	8	35	4	36
		Substile.			
X	II	6	25	3	28
XI	I	21	25	11	56
XII	XII	36	25	21	41
I	XI	51	25	34	03
II	X	66	25	51	00
III	IX	81	25	74	21

IV. *To find the Angle that each Hour maketh with the Substile.*

And for the finding of those Angles, this is the Proportion.

As the Sine of 90 deg. ——— 10—00000

Is to the Sine of the height of the Pole above the Plain 32 deg. 36 min. ——— 9—73140

So is the Tangent of the Equinoctial distance of the next hour to the Substile, *viz.* 6 d. 25 m. ——— 9—05101

To the Tangent of 3 deg. 28 min. ——— 8—78241

Which 3 deg. 28 min. is the distance of the Ten or Two a Clock Hour-lines from the Substile. So again.

Figure I.

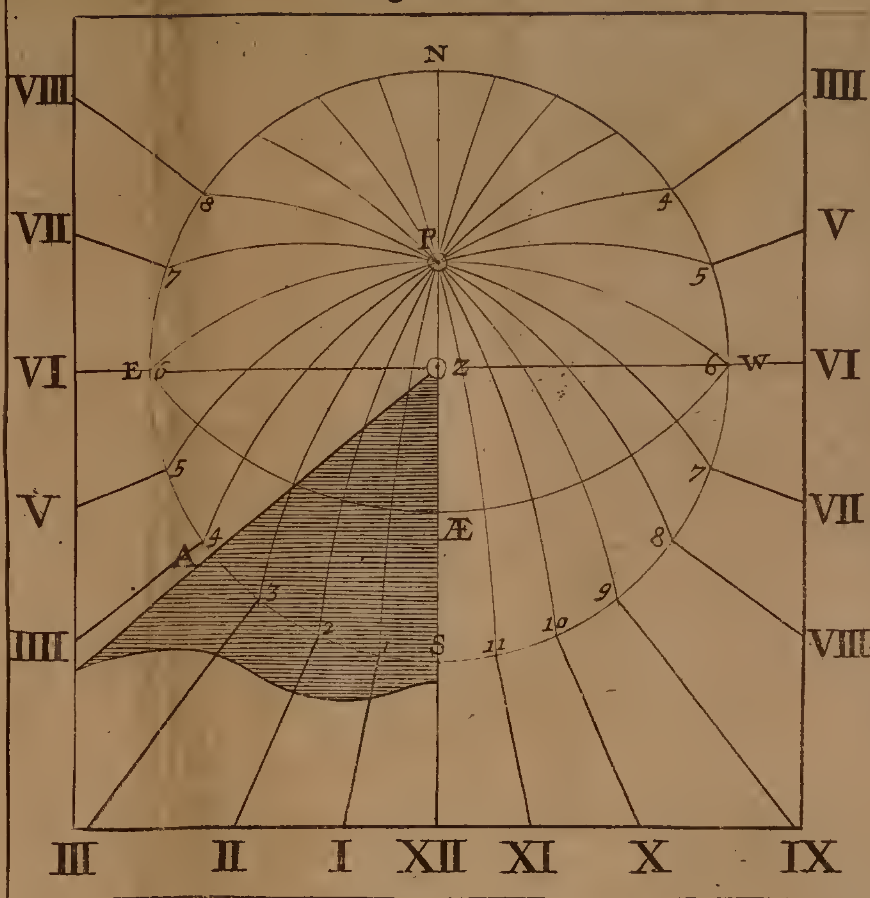


Figure II.

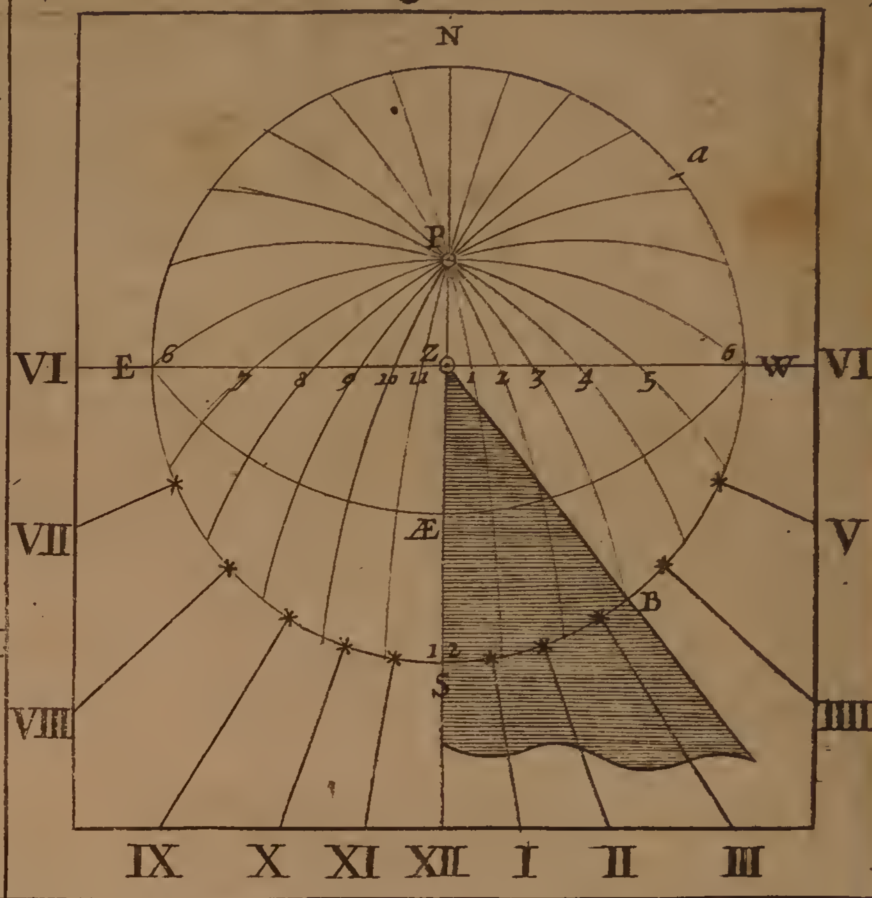
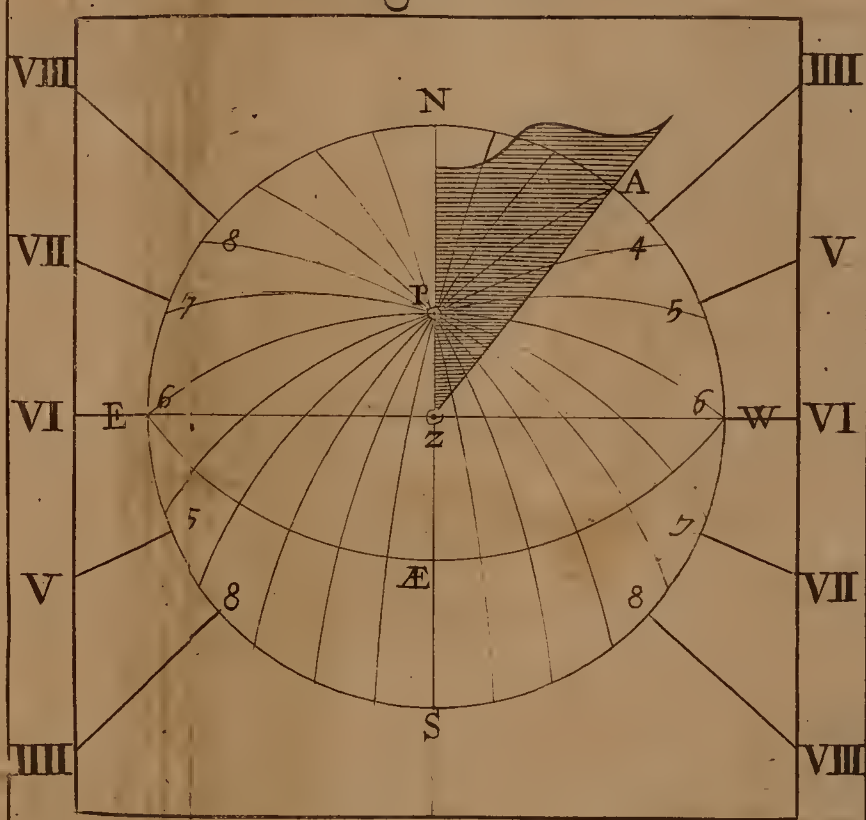


Figure III.



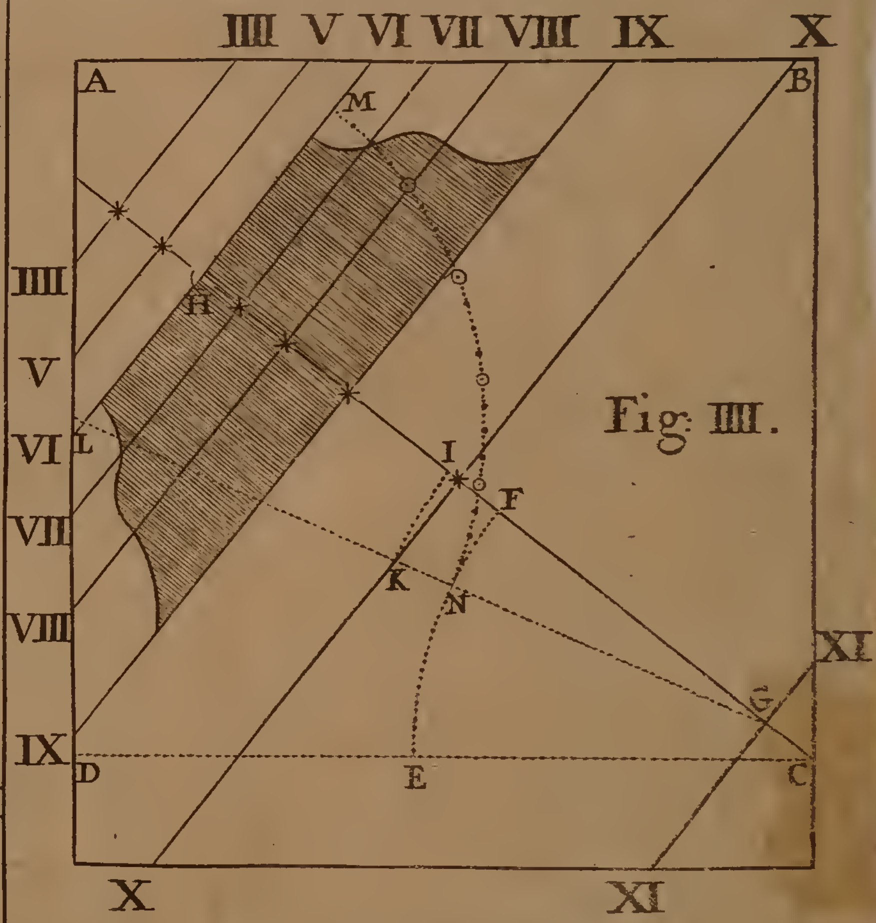


Fig: IIII.

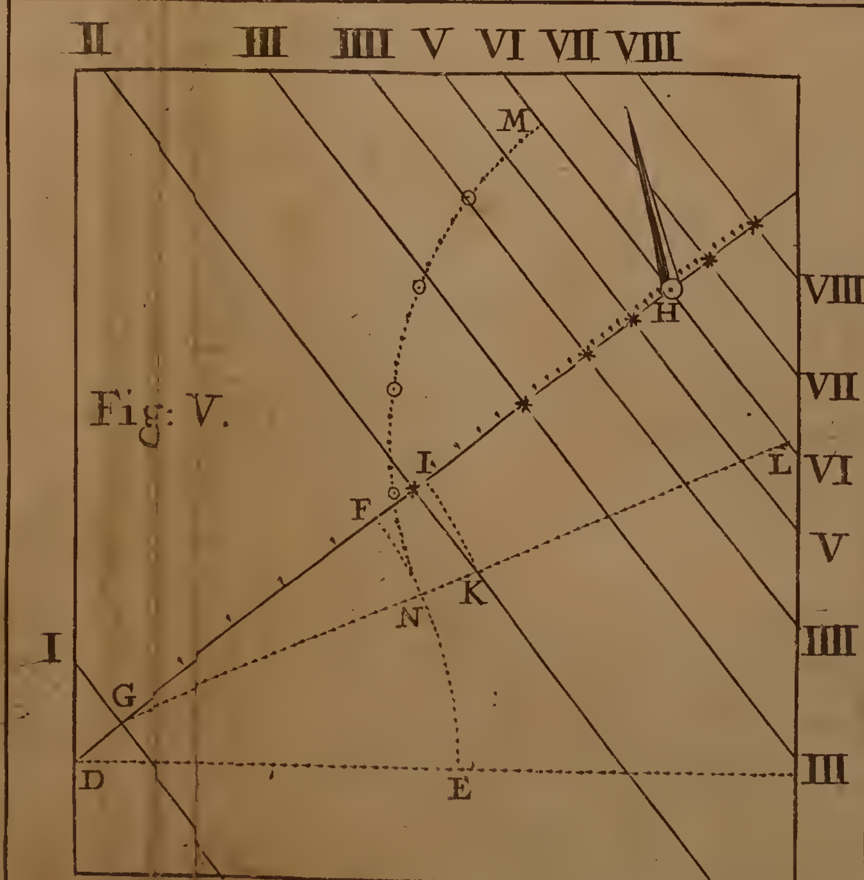


Fig: V.

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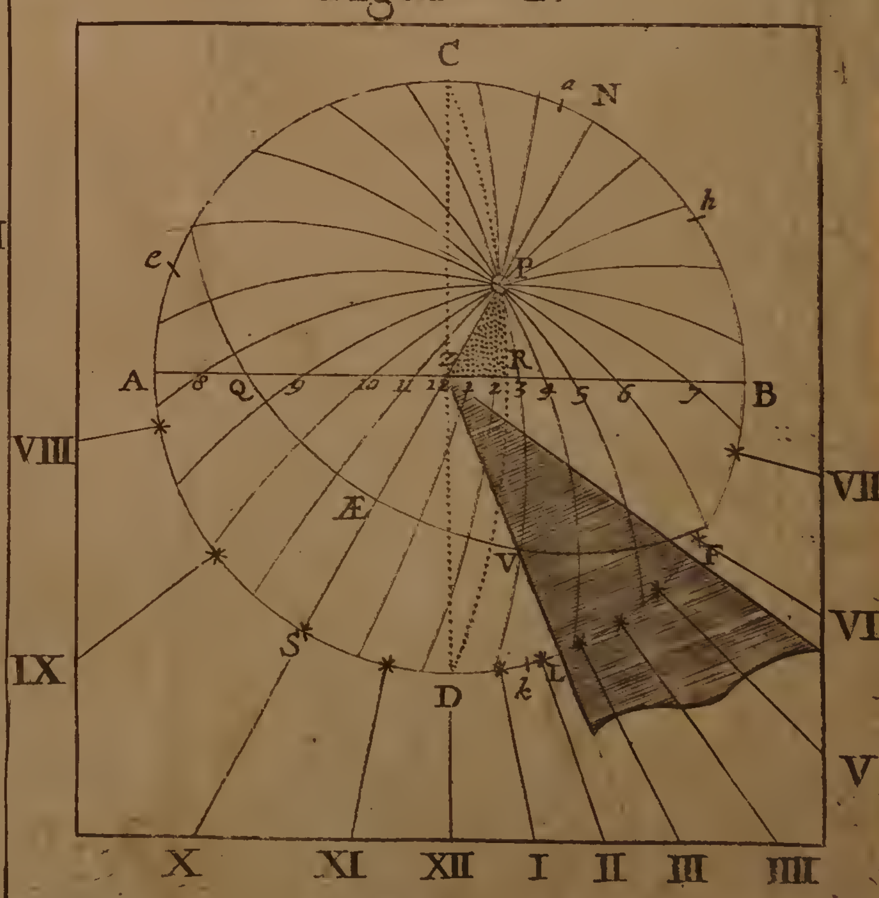
Figure VI.



4

As the Sine of 90 deg.——10—00000

To the Sine of the Stile's height 32 deg. 36 min.——9—73140
So the Tang. of the next Equin. dist. 21 deg. 25 min.——9—59354

To the Tangent of 11 deg. 56 min.——9—32494

Which 11 deg. 56 min. is the Distance of the Hour-Lines of Eleven or One of the Clock from the Substile. And so of all the rest, as in the Table: Which being measured upon the Primitive Circle by help of a Scale of Chords, will be found the same as where the Hour-Circles of the Projection did cut the Primitive Circle.

CHAP. XIII.

How to draw Hour-Lines upon a South *or* North-Plain, *which declines many* Degrees *towards the* East *or* West.

If a Plain shall be found to decline many Degrees from the *North* or *South* towards either *East* or *West*; as, above 60 deg. Although the *Requisites* may be found, and the *Dial* made in all respects as the former *Dial* was in the last *Chapter*, yet by reason that the *Pole* of the *World*, will have but small Elevation above such a *Plain*, the *Hour-Lines* will fall so close one to another, that there will be no competent distance between them, till they be extended very far from the *Center*: And therefore, it was the way of the Ancients, to draw the Dial upon a large Floor, and extend the *Hour-lines*, *Stile* and *Substile*, to a great length, that so the *Hour-lines* might be of a convenient distance; and then to cut the *Dial* off, *Stile* and all, and so transfer it to the *Plain*. But this being too *Mechanical*, I will here shew a more artificial way how to draw such a *Dial Geometrically*, by help of a *Line of Chords* only, having no regard to the Center of the Dial. And,

I. *By* Trigonometrical *Calculation*.

You must find the *Requisites*: Namely, (1.) *The height of the Pole, or Stile, above the Plain.* (2.) *The distance of the Substile from the Meridian.* (3.) *The Plain's difference of Longitude.* All which may be found by the foregoing *Analogies*, or *Proportions*.

Suppose therefore, An Upright Plain, in the Latitude of 51 deg. 32 min. should decline from the *South*, *Eastward* 85 deg.

I. *For the* Stile's *height*.

As the Radius 90 deg.——10—00000

To the Co-Sine of the Latitude 38 deg. 28 min.——9—79384
So is the Co-Sine of the *Plain's* declination 5 deg.——8—94029

To the Sine of 3 deg. 6 min. the height of the Pole or Stile——8—73413

II. *For the* Subſtile's *Diſtance from the* Meridian.

As the Radius 90 deg.————————————10—00000

To the Sine of the Declination 85 deg.————9—99834
So is the Co-Tangent of the Latitude 38 deg. 28 min.—9—90008

To the Tangent of 38 deg. 22 min.————————9—89842
For the *Deflection*, or the *Subſtile*'s diſtance from the *Meridian*.

III. *For the* Plain's *Difference of Longitude*.

As the Sine of the Latitude 51 deg. 32 min.————9—89374

Is to the Radius 90 deg.———————————10—00000
So is the Tangent of the Declination 85 deg.————11—5 804

To the Tangent of 86 deg. 5 min.———————11—16430
Which is the *Plain*'s Difference of Longitude.

Theſe *Requiſites* being thus found, you may proceed to the making of a Table for the Hour-Diſtances, in all reſpects as in the laſt Chapter: By firſt ſetting down the Hours proper for the Plain in Order, as in this Table: And againſt XII, ſet the Difference of Longitude 86 deg. 5 min. from which ſubſtract 15 deg. and there will remain 71 deg. 5 min. which ſet againſt XI and I. Alſo from 71 deg. 5 min. ſubſtract 15 deg. the remainer will be 56 deg. 5 min. which ſet againſt X and II; and ſo by the continual Subſtraction of 15 deg. you ſhall find 11 deg. 9 min. to ſtand againſt VII and V, under which write *The Subſtile's Place*, and then 11 deg. 5 min. being ſubſtracted from 15 deg. there will remain 3 deg. 55 min. which ſet under *The Subſtile's Place*, againſt VI; and then by the continual addition of 15 deg. thereto, you ſhall have ſuch Equinoctial Diſtances, as the ſecond Column of the Table affordeth: And then for the true Hour-diſtances upon the Plain, ſay

As the Radius 90 deg.——————————10—00000

To the Sine of the Stile's height 3 deg. 6 min.———8—73302
So is the Tangent of 86 deg. 5 min. the Equinoctial diſtance of XII————— }———11—16453

To the Tangent of 33 deg. 23 min.———————9—89755

Which is the diſtance of XII a Clock from the Subſtile, upon the Plain; And ſo proceeding with the reſt of the Equinoctial Diſtances, you ſhall exhibit ſuch Numbers as the Third Column affordeth.

	D.	M.
South Declin. Weſt	85	00
Diſtance Subſtile and Meridian	39	22
Height of the Stile	3	06
Plain's difference of Longitude	86	05

By

Hours East	West	Equinoctial Distances D.	M.	Hour-dist. on the Plain D.	M.
XII		86	5	38	23
XI	I	71	5	8	58
X	II	56	5	4	36
IX	III	41	5	2	42
VIII	IV	26	5	1	31
VII	V	11	5	0	36
The Substiles Place					
VI		3	55	0	13
V	VII	18	55	1	4
IV	VIII	33	55	2	6

By this Table you may ſee that the Hour-diſtances about the Subſtile (and indeed all the reſt except the extream Hour of XII) do fall ſo near together, that without an infinite extention of them, there will be no competent Diſtance between Hour-line and Hour-line; wherefore, laying aſide your Table, proceed to make your Dial Geometrically, according to theſe following Directions.

The Geometrical Projection of this (or the like) Dial.

1. Draw a right-line A B perpendicular to one ſide of your Plain, and towards the Right-hand, becauſe the Plain declineth *Eaſtward*; and with 60 deg. of your Line of Chords, deſcribe an obſcure Arch of a Circle C D E, and upon it (from C to D) ſet off 38 deg. 23 min. the *Subſtile's diſtance* from the *Meridian*, and draw the Line A D for the *Subſtile*, quite through the Plain. *Figure* VIII.

2. Out of your Line of Chords take 3 deg. 6 min. the height of the *Stile*, and ſet them upon the former Arch from D to E, and draw the Line A E for the *Stile*.

3. Now (becauſe the *Stile* is but of ſmall *Elevation*, *viz.* but 3 deg. 6 min.) draw another Line (as G H) parallel to the Line of the *Stile* A E, at ſuch convenient diſtance as you ſhall think fit; which ſhall be your *Augmented Stile*.

4. Aſſume any two Points in the *Subſtilar Line* A D, at ſome convenient diſtance each from other, as R and S, and through thoſe two Points draw two infinite Right-lines, both of them at Right Angles to the *Subſtilar Line* A D, as the Lines Z Z, and X X.

5. From the Point R, with your Compaſſes take the neareſt diſtance to the new *Augmented Stile* G H, and ſet that diſtance upon the *Subſtilar Line* from R to K.——Alſo, from the Point S, take the neareſt diſtance to the new *Augmented Stile* G H, and ſet that diſtance alſo upon the *Subſtilar Line* from S to L.

6. Upon theſe two Points K and L, with 60 deg. of the Line of Chords, deſcribe two *Semicircles*, and in either of them ſet off 86 deg. 5 min. the Plain's difference of Longitude; as from R to M, and alſo from S to M; both of them on the ſame ſide of the *Subſtilar Line*, on which the firſt perpendicular Line A B was drawn.

7. Divide either of the *Semicircles* laſt drawn into 12 equal Parts, beginning at the point M, as the Points ⊙⊙⊙, *&c.* which 15 deg of the Line of Chords will effect-

8. Lay a Ruler to the Point L, and the reſpective Points ⊙⊙⊙, *&c.* in the Semicircle, and the Ruler will cut the Line X X in the Points *** *&c.*——Alſo lay a Ruler to K, and the ſeveral Points ⊙⊙⊙, *&c.* and the Ruler will cut the Line ZZ in the ſeveral Points ***, *&c.*

Laſtly, Lines drawn from the firſt Point * in the Line ZZ, to the firſt Point * in the other Line XX, (which the *Subſtilar Line* will di- rect

rect you how to do) those Lines so drawn shall be the true Hour-lines proper for the Plain, and will appear as in the Figure, and be at a competent distance one from another, without having any relation at all to the Center.

Now in the making of this Dial you have made four Dials, *viz.*

A { South declining West / South declining East / North declining West / North declining East } 85 degrees

only by changing of the names of the Hours, and placing the *Stile* on the contrary side of the Line AB, for the South declining East. And by turning of the Dial upside downwards, for the two North Decliners; so that the Stiles may point upwards to the North-Pole, and the Hours about Midnight be omitted, as in the former North Dial, Figure VII.

CHAP. XIV.

How to draw the Hour-lines upon a Direct East *or* West Reclining Plain.

I. *By the* Projection.

Suppose a direct *West Plain* should Recline from the *Zenith* 35 deg. in the *Latitude* of 51 deg. 32 min. As in all Upright Plains, whether *Direct* or *Declining*, the *Meridian of the Place* and Hour-line of 12, is always *Perpendicular* to the *Horizon*: So in all *Direct East* and *West Reclining*, or *Inclining Plains*, the *Meridian* of the *Place* and *Hour-line* of 12, is parallel to the *Horizon*. To make these Dials.

Figure IX. First, Draw a Right-line NZS, representing the *Base* of your *Reclining Plain*, and Hour-line of 12: Upon Z, describe a Circle, and draw the Diameter W E, to cut the Line N S at Right Angles in Z. Upon Z describe a Circle, and upon the *Meridian Line* N S, set off the Pole of the World from Z to P, answerable to the Complement of the Latitude of the Place, and finish your *Projection* as hath been already taught.

Secondly, Because the Plain Reclines 35 deg. take 35 deg. out of a Scale of *Chords*, and set it from S to *a*, a Ruler laid from N to *a*, will cut the *Vertical* Line of the Plain in O, and now have you three Points, N, O, and S, whereby to draw your *Reclining Plain*, whose Center will alwayes be in the Line E W extended; Or, 35 deg. the *Reclination*, being taken out of a Scale of *Half Tangents*, will give the point O as before. The Circle N O S representing the *Reclining Plain*, being drawn, you must find its *Pole*, which may be done in this manner: Take 90 deg. out of the Line of *Chords*, and set them from *a* to *b*, a Ruler laid from N to *b*, will cut the *Vertical Line* of the *Plain* E W, in Q, for the Pole of the *Reclining Plain* (or the complement of the Reclination 55 deg. being taken out of a Scale of *Half Tangents* and set

ſet from Z, will find the point Q for the Pole of the Plain alſo). Now having found the *Pole of the Plain* at Q, and the *Pole of the World* at P, you have two Points, *viz.* P, and Q, through which you muſt (by the 12th Problem of the *Introduction*) draw an Arch of a *Great-Circle*, which will cut the *Reclining Plain* at Right-Angles in R: Now part of the Arch of this *Circle*: Part of the *Meridian* N P: And part of the *Reclining Plain* N R, do conſtitute a *Spherical Triangle* N R P, Right Angled at R. And out of this Triangle may all the *Requiſites* belonging to this *Plain* be found, which are Three, *viz.*

I. The *Height of the Pole above the Plain,* repreſented by the Arch P R.

II. The *Diſtance of the Subſtile and Meridian,* repreſented by N R.

III. The *Plain's difference of Longitude*, or the *Angle between the Meridian of the Place, and the Meridian of the Plain,* repreſented by the Angle N P R.

Firſt, you muſt find the Pole of the *Meridian* of the Plain, Which will always be where the Circle N O S, repreſenting the Plain, doth croſs the Equinoctial Circle, as here it doth at A; ſo is A the Pole of the Meridian of the Plain. And now,

1. *To find the Height of the Pole or Stile above the Plain,*] A Ruler laid from A to P, will cut the Circle in *e*, and laid from A to R, it will cut the Circle in *c*, the diſtance *e c* meaſured upon a Scale of *Chords* will give 26 deg. 41 min. for the *Stile's Height.*

2. A Ruler laid from Q to R, will cut the Circle in L, the diſtance N L 45 deg. 52 min. Is the *diſtance of the Subſtile from the Meridian.*

3. A Ruler laid from P to B, where the *Meridian of the Plain* cuts the *Equinoctial Circle* E Æ W, will cut the Circle in *g*, (or where the Meridian of the Plain cuts the Primitive Circle, which is in *g* alſo,) the diſtance S *g* 66 deg. 27 min. is the *Plain's difference of Longitude*, or the *Angle between the Meridian of the Plain, and the Meridian of the Place.*

The *Requiſites* being thus found, the *Hour-lines* are eaſily drawn. For lay a Ruler from Q, the *Pole of the Plain*, to the ſeveral *Points* where the *Hour-Circles* croſs the *Reclining Plain*, as at 1, 2, 3, &c. and where the Ruler cuts the *Primitive Circle* make marks, or ***, thro' which marks if you draw Lines from Z, they ſhall be the true *Hour-Lines* proper for your *Reclining Plain.* And a Ruler laid from Q to R gives the Point L for the Subſtile. The height of the Stile being 26 deg. 41 min. ſet 26 deg. 41 min. from L to F, and draw the Line Z F for the *Stile.* And ſo is the Dial Finiſhed: And in making of this Dial you have made an *Eaſt Reclining* alſo, by only turning the Dial about, and numbering the Hours contrary, as in the Upright Decliners.

II. *By* Trigonometrical *Calculation.*

You muſt firſt find all the *Requiſites* belonging to the Plain, all which may be obtained by reſolving the *Right angled Spherical Triangle* N R P Right angled at R.

I. *For the Height of the Pole or Stile above the Plain.*

As the Radius, the Sine of 90 deg.	10.00000
Is to the Sine of the Latitude P N 51 deg. 32 min.	9.89374
So is the Sine of the Plain's Reclination R N P 35 deg.	9.75859
To the Sine of 26 d. 41 m. the side P R, the Stile's height above the Plain.	9.65233

II. *For the Substile's distance from the* Meridian.

As Radius	10.00000
To the Tangent of the Latitude 51 deg. 32 min. N P	10.09991
So is the Co-sine of the Reclination 55 deg.	9.91336
To the Tangent of 45 deg. 52 min. N R, the distance of the Substile and Meridian.	20.01327

III. *For the Plain's Difference of Longitude.*

As the Sine of the Latitude 51 deg. 32 min. P N	9.89374
Is to the Radius 90 deg.	10.00000
So is the Sine of the Substile's distance from the Meridian 45 deg. 52 min. N R	19.85595
To the Sine of 66 deg. 27 min. The Plain's difference of Longitude R P N.	9.96221

The *Requisites* being found, you are next to prepare a *Table* as followeth, wherein set the Hours proper for the Plain, namely, from 4 in the Morning till 2 in the Afternoon, for the *East Recliner*, and from 10 in the Forenoon till 8 at Night, for the *West Recliner*.

Then, considering the Plain's *Difference of Longitude* to be 66 deg. 27 min. consider how many *Equinoctial Hours* are therein (allowing 15 deg. for an Hour) and you shall find 4 Hours, and 6 deg. 27 min. remaining, wherefore the Substile must stand between the Hours of 4 and 5 in the *East Dial*, and between 7 and 8 in the *West Dial*, between which Hours write the word *The Substile*: Then, because there is 6 deg. 27 min. remaining above 4 hours, write 6 deg. 27 min. in the second Column over *Sub-* against the Hours of 4 and 8. Also substract 6 deg. 27 min. from 15 deg. the Remainer will be 8 deg. 33 min. which write under *The Substile* against the Hours of 5 and 7. Then by the continual addition of 15 deg. to either of these Numbers, you shall have the *Equinoctial distances* belonging to each Hour, as in the second *Column* of the *Table*, namely, 21 deg. 27 min. for 9 and 3; And 23 deg. 33 min. for 6 and 6, *&c.*

The

West Reclining	35	0
Latitude	51	32
Stile's height	26	41
Deflection	45	52
Difference of Long.	66	27

Hours from the Substile		Equinoctial Distances. D.	M.	Hour-distances from the Substile. D.	M.
11	1	81	27	71	29
12		66	27	45	52
1	11	51	27	29	24
2	10	36	27	18	20
3	9	21	27	10	0
4	8	6	27	2	54
The		Sub-		stile.	
5	7	8	33	3	52
6	6	23	33	11	4
7	5	38	33	19	41
8	4	53	33	31	18
9	3	68	33	48	49
10	2	83	33	75	50

The *Table* being thus Prepared, you have nothing now to do, but to Calculate the Hour-distances upon the Plain from the *Substile*; which is easily done by this general *Analogy* or *Proportion.*

As the Radius	10.00000
Is to the Tangent of 6 d. 27 m. the Equinoctial dist. for the hours of 4 and 8	9.05328
So is the Sine of the Stile's height P R 26 deg. 41 min.	9.65233
To the Tangent of 2 deg. 45 min. the dist. of the Hours of 4 and 8 upon the Plain from the Subst.	8.70561

And by continual working of this *Proportion*, you shall find such numbers as this Table affordeth in the Third *Column* thereof, which being set off by help of a Scale of Chords upon a Circle from the *Substile* of the Dial, they shall be the true *Hour-lines* proper for your *Reclining Plain.*

CHAP. XV.

How to draw Hour-Lines upon direct South Reclining Plains.

The First Variety, Reclining *Equal to the* Pole.

Of these Plains, there are *Three Varieties*: For, First, the *South* Plain may so Recline, that it may fall just into the Pole, and that is when the *Reclination* of the *Plain* is equal to the *Complement of the Latitude of the Place*, Over such a Plain the *Pole* hath no *Elevation*, and therefore the *Dial* no *Center*, and all the *Hour-Lines* must be *parallel*; and the making of this Dial is the same as the *East* or *West Erect-direct Dials* where, only, as the Stile of those Dials stood upon the Hour-Line of *Six*, in these it must stand upon the Hour-Line of *Twelve*, and the Equinoctial Line in that, must be an Horizontal Line in this. An Example of such a Plain you have in Figure X. *Figure* X.

II. *The* Second Variety, *South* Reclining *Less than to the* Pole.

Having drawn a Circle W S E N, and crossed it with two Diameters S N, for the *Meridian* of the Place and the Hour-Line of 12, and W E for *Figure* XI.

for the *Prime Vertical* Circle, and Hour-Line of *Six*, and within this Circle Projected the *Sphere* according to the former Directions, you may now proceed to the making of the Dial; Which, Let be a *South Plain, Reclining* from the *Zenith* 25 Degrees.

I. *By the* Projection.

The *Reclination* of the Plain being 25 deg. take 25 deg. from a Chord, and set them from E to *a*, a Ruler laid from W to *a*, will cut the Meridian of the Place in R: Or, the half Tangent of 25 deg. will reach from Z to R also: And now you have three Points W, R, and E, whereby to draw your *Reclining Plain*, whose Center will always be in the Meridian Line S Z N extended, and from its Center to R, will be equal to the *Secant* of 70 deg. the Complement of the Reclination.

The Circle W R E representing the Plain, being drawn, you see that it passeth between the *Pole of the World* and the *Zenith*, and therefore the *South Pole* is Elevated above it; and how much, you may thus find; Lay a Ruler from W to P, it will cut the Circle in *c*, the distance from *c* to *a* measured upon a Chord, will be found to be 13 deg. 28 min. for the height of the *South Pole* or Stile above the Plain.

For finding the *Pole* of the *Plain*, take 90 deg. of the Chords, and set them from *a* to *b*, a Ruler laid from W to *b*, will cut the *Meridian Line* S N in Q, so is Q the *Pole* of the *Plain*.

Now for the *Hour-Lines*, Lay a Ruler to Q, and to the several Points 1, 2, 3, *&c.* where the Hour-Circles of the Projection intersect with the Plain W R E, and on the Circle, where the Ruler crosseth it, make marks ***, and from Z the Center, through those marks, draw Lines, and they shall be the true Hour-Lines proper to the Reclining Plain; and 13 deg. 28 min. set from N to L shall give the Point L, whereby to draw the Line Z L for the Stile of the Dial.

II. *By* Trigonometrical *Calculation.*

In these Plains there is nothing (besides the Hour-Distances) to be found, but *The height of the Pole or Stile above the Plain*, and that is easily done: For, The *Plain* falling between the *Pole* and the *Zenith*, if you substract the *Reclination* Z R 25 deg. from Z P 38 deg. 28 min. the *Complement of the Latitude*, the Remainder 13 deg. 28 min. is the *Height of the Pole above the Plain.*

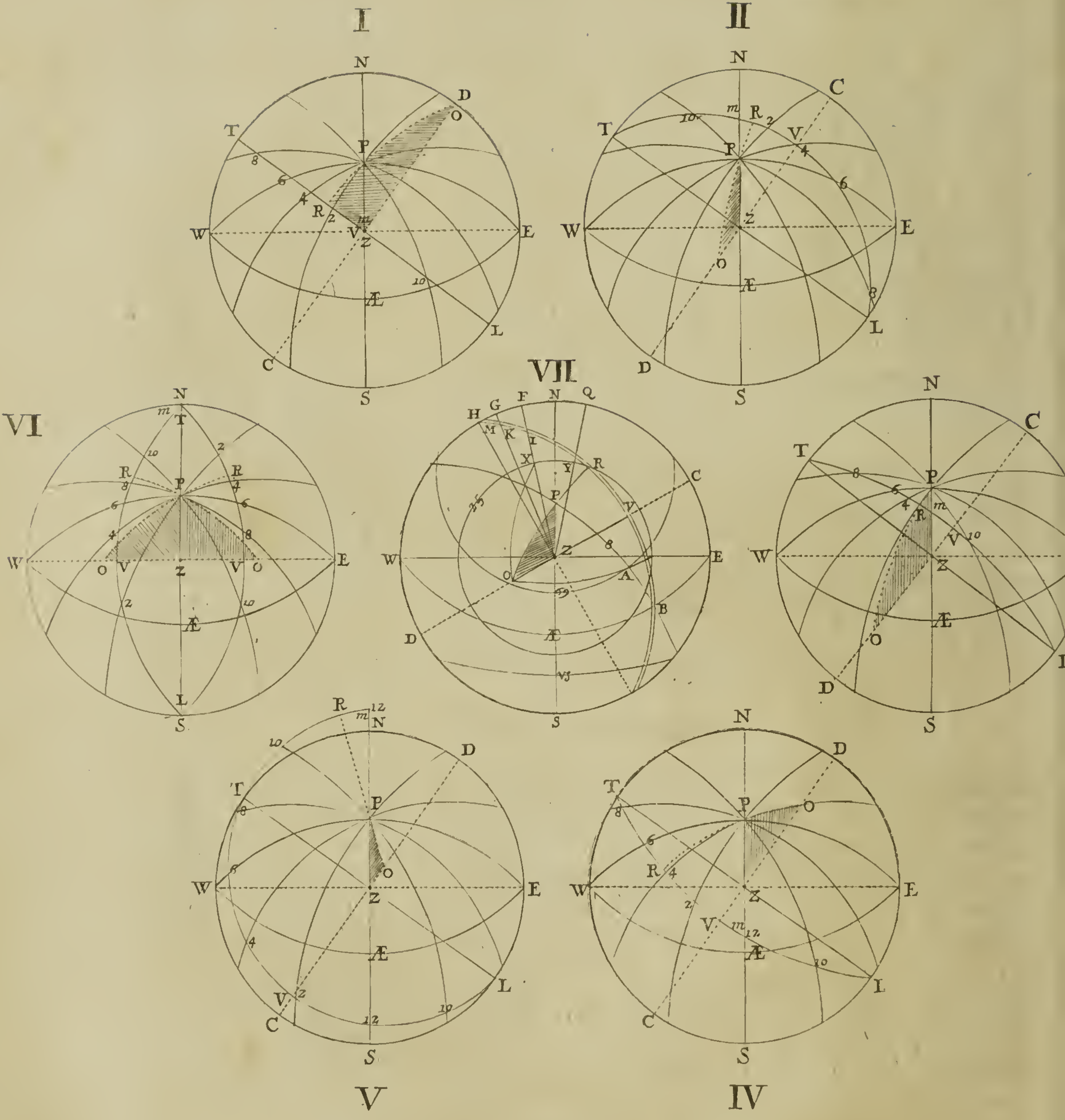
Stile's height 13 d. 28 m.					
Hours from Noon.		Equinoctial Distances. D.	M.	Hour-Distances on the Plain. D.	M.
12		0	0	0	00
11	1	15	0	3	34
10	2	30	0	7	39
9	3	45	0	13	7
8	4	60	0	21	58
7	5	75	0	41	0
6		90	0	90	0

Now for the *Hour-Lines*, the height of the Pole above the Plain being found, the general *Canon* for Hour-distances will effect that; for having framed a *Table* with *Hours* and *Equinoctial distances* answerable to them, you may by the general Canon work as followeth.

As the Radius 90 deg. · 10.00000

To the Sine of R P 13 d. 28 m. the height of the Pole above the Plain. } 9.42805

So



Against ye begining of ye Seventh Tractate Page 49.

So is the Tangent of 15 d. the Equinoctial dist. for 1 and 11, 9.36713

To the Tangent of 3 d. 34 m. the Hour-distances of 11 and 1 a Clock } 8.79518

And so for all the Rest of the Hour-distances as in the Table, the Stile being 13 deg. 28 min. high, set it upon the Circle from N to L, and draw the Line Z L for the Stile, The Substile is always the Meridian or Hour-Line at 12.

III. *The* Third Variety, South *Reclining* More *than to the* Pole.

The Lines N S and E W being drawn at Right Angles in Z, the one for the *Meridian* and Hour-Line of 12, the other for the *Prime Vertical* Circle and Hour Line of Six: And the *Sphere Projected* upon the *Horizon of London* according to former Directions, You may proceed to the drawing of the *Dial* in this manner, nothing differing from the former: And let the Example be of a direct *South* Plain *Reclining* 70 deg. *Figure* XII.

I. *By Projection.*

The Sphere being Projected, describe the Circle representing the Plain upon it, in this manner: The *Reclination* being 70 deg, take 70 deg. of your Chord and set them from E to *a*, A Ruler laid from W to *a*, Will cut the Meridian in R, (or the half Tangent of 70 deg. set from Z, will give the Point R also) and so you have three Points through which to describe the Circle E R W representing your *Reclining Plain*, whose Center will be in the Meridional Line N S: And the Secant of 20 deg. (the Complement of the *Reclination*) set from R upon the *Meridian Line* to B, will give the Center: And the Plain being described, you see it falls between the *Pole* and the *North* Point of the *Horizon*, and therefore the *North Pole* is Elevated, and to know how much, Lay a Ruler from W to P, it will cut the Circle in *b*, so the distance between *a* and *b* being measured upon the Scale of Chords, will give 31 deg. 32 min. for the height of the *Pole* or *Stile* above the *Reclining Plain.*

Next find the *Pole* of the *Plain* E R W, by taking 90 deg. of your Chords, and setting it from *a* to *c*, a Ruler laid from W to *c* will cut the *Meridian* in Q, so is Q the *Pole* of the *Plain*; To which Point and the several intersections of the *Hour-Circles* of the *Projection* with the *Plain*, 1, 2, 3, *&c.* If to these Points you lay a Ruler, it will cut the Primitive Circle in ***, *&c.* through which Points if you draw right Lines from Z, they shall be the true Hour-Lines: And 31 deg. 32 min. the height of the Pole above the Plain, being taken from a Chord, and set from N to L, it shall give the Point whereby to draw the *Stile*: And so is the *Dial* finished.

 II. *By*

II. *By* Trigonometrical *Calculation.*

There is nothing in this Dial to be Calculated but the *Hour-Diſtances*, and before you can Calculate them, you muſt firſt obtain *The height of the Pole* or *Stile above the Plain*, in this manner: The Plain falling between the *Horizon* and the *North Pole*, the Arch of the *Meridian* P R, muſt be the height thereof: Now from Z to R is 70 d. the *Reclination* of the Plain, and from Z to P is 38 deg. 28 min. the *Complement* of the *Latitude*: Subſtract P Z 38 deg. 28 min. from Z R 70 deg. the remainder 32 deg. 31 min. is the *Arch* P R, the height of the *Pole* above the *Plain*: Which known, prepare a *Table* and Calculate the *Hour-diſtances* by the general Analogie or Proportion.

Stile's height 31 d. 32 m.					
Hours from Noon.		Equinoctial Diſtances.		Hour-Diſtances on the Plain.	
		D.	M.	D.	M.
12		0	0	0	00
11	1	15	0	7	59
10	2	30	0	16	48
9	3	45	0	27	36
8	4	60	0	42	10
7	5	75	0	62	52
6		90	0	90	0

As Radius	10.00000
To the Sine of the height of the Pole above the Plain P R 31 deg. 32 min.	9.71850
So is the Tangent of 15 deg. the Equinoctial diſtance	9.42805
To the Tangent of 7 d. 59 m. the Hour-diſt. of 11 or 1.	9.14655

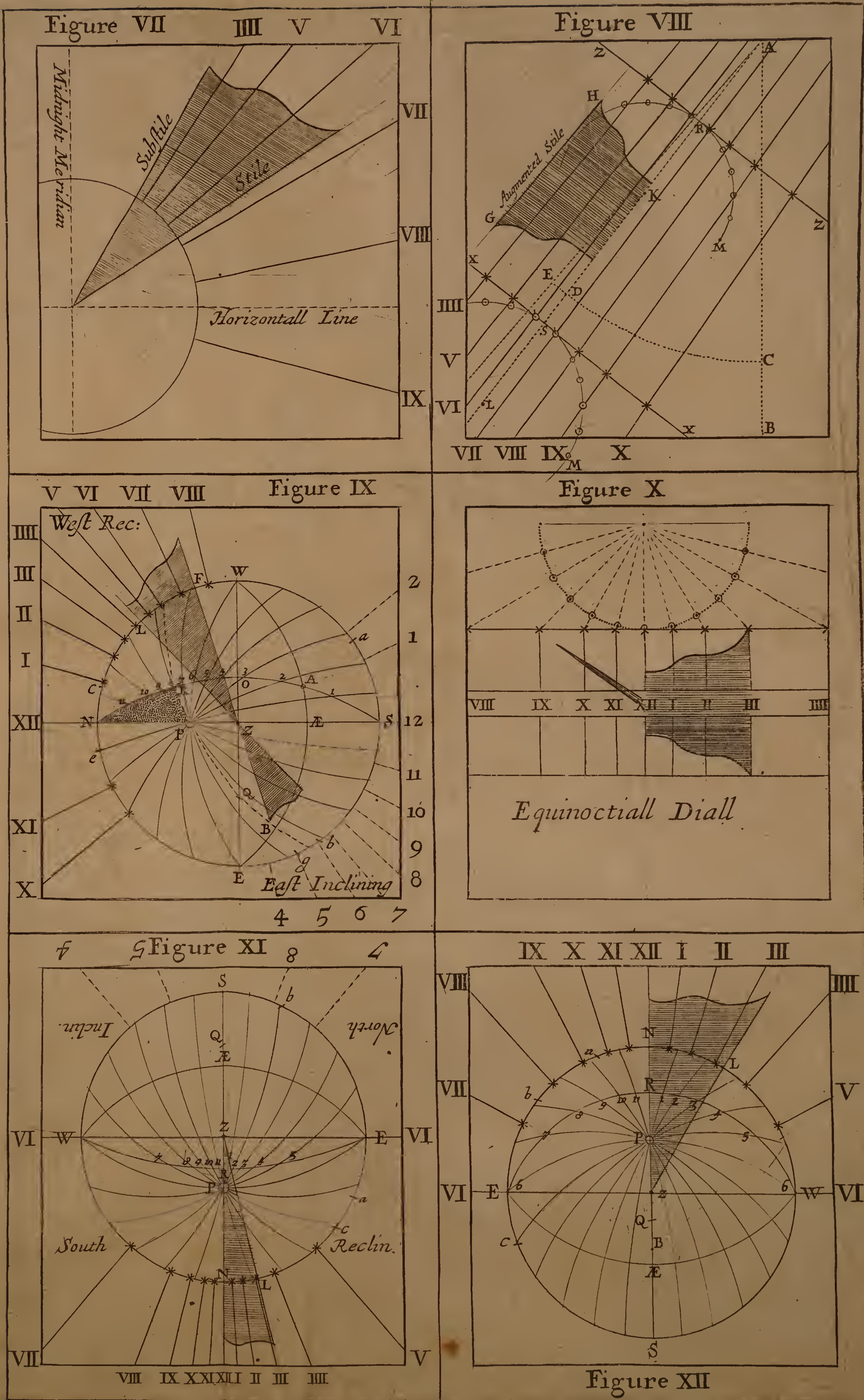
And ſo for all the reſt of the Hour-Diſtances as in the Table, The Stile muſt be Elevated above the *Meridian* or Subſtile equal to the Angle N Z L 31 deg. 32 min. And ſo is the Dial finiſhed.

CHAP. XVI.

How to draw Hour-lines *upon direct* North Reclining Plains.

OF theſe kind of *Plains* there are Three *Varieties*, as there were of *South Recliners*: For (1.) The *Reclination* may be ſuch that the *Plain* may juſt lie to the *Equinoctial Circle.*——Or, (2.) It may *Recline* ſo, that the *Plain* may fall between the *Zenith* and the *Equinoctial Circle.* Or, (3.) The *Plain* may *Recline* ſo, as to fall between the *Equinoctial* and the *Horizon. Examples* of all which do here follow.

I. *The*



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I. *The First* Variety; North Reclining, *Equal to the* Equinoctial.

I. *By Projection.*

Our first Example shall be of a *North Plain*, *Reclining* from the *Zenith*, 51 deg. 32 min.

First, Having drawn N S for the *Meridian* and Hour-Line of 12, and E W for the *Prime Vertical Circle*, and Hour-Line of 6, crossing each other at Right Angles in Z, and upon Z described a Circle, and therein *Projected* the *Sphere*: The next thing to be done is to project the *Circle* representing your *Reclining Plain*: And the *Reclination* being 51 deg. 32 min. take those Degrees from your Line of Chords and set them from W to *a*: A Ruler laid from E to *a*, will cut the *Meridian* in Æ, which is the very intersection of the *Equinoctial Circle* with the *Meridian* N S; and so the *Equinoctial Circle* represents your Plain: To find the *Pole* whereof, Take 90 deg. of your Chords and set them from *a* to *b*, and laying Ruler from E to *b*, it will cross the Meridian N S in P the Pole of the World, so that the *Pole* of the *World* is the Pole of this Plain; and the distance *a b* being 90 deg. shews the *North Pole* to be elevated above the *Plain* 90 deg. Figure XIII.

Now for the Hour-Lines, P being the Pole of the Plain, lay a Ruler thereto, and to every of the Hour-points 1, 2, 3, *&c.* 11, 10, 9, *&c.* where the *Hour-Circles* cross the Plain, and where the Ruler crosseth the *Primitive Circle*, make marks * * *, through which, and the Center Z, Lines being drawn shall be the true Hour-Distances proper for this *Reclining Plain*: And indeed they are no other than if the Circle were divided into 24 equal parts, for the Hours are all of an equal distance one from another, namely 15 deg. Now the Stile having 90 deg of Elevation, A straight *Pin* or *Wyre* of any length, set upright, *(i. e.) Perpendicular to the Plain*, in the point Z, shall point directly to the *North Pole*, and so shew the Hour by the shadow thereof.

There needs no *Trigonometrical Calculation* for this *Dial*, the Hour-Distances being all Equal, *viz.* 15 Degrees from each other, and the Stile only a *straight Wyre*, set perpendicular to the Plain.

II. *The Second* Variety; North Reclining *Less than the* Equinoctial.

I. *By Projection.*

Let this Second *Example* be of a North Plain, *Reclining* from the *Zenith* 25 deg. Having drawn N S for the *Meridian*, and E W for *Prime-Vertical*, intersecting at Right Angles in Z, and upon Z described a Circle E N W S, and in it *Projected* the *Sphere*; Your next work will be to Draw the Circle representing the Plain upon the *Projection*, in this manner: Figure XIV.

The Plain Reclining 25 deg. take 25 deg. out of your Line of Chords, and set it from W to *a*: A Ruler laid from E to *a* shall cut the Meridian

Meridian in R, (or the half Tangent of 25 deg. ſet from Z, ſhall give the Point R alſo). And now you have Three points to draw your plain by, *viz.* E R W, whoſe Center will be in the *Meridian* Line N S, and the Secant of 25 deg. ſet from R will give the ſame.

The Plain being thus deſcribed, you ſee it paſſeth between the *Zenith* and the *Equinoctial*, and the *North Pole* is Elevated above it the Quantity of the *Arch* of the *Meridian* R P; and to know how much that is, you muſt firſt find the Pole of the Plain thus: Set 90 deg. from *a* to *b*, then lay a Ruler upon E and *b*, it will cut the Circle in Q, ſo is Q the pole of the Plain; and a Ruler laid from E to P will cut the Circle in *c*, the diſtance *a c* meaſured upon a Scale of Chords will give 63 deg. 28 min. for the Arch P R, equal to the height of the Pole above the Plain.

To draw the Hour-Lines; Lay a Ruler upon Q, and to the ſeveral points where the Hour-Circles croſs the Plain, and where the Ruler cutteth the *Primitive Circle* make marks or * * *, through which points, from the point Z, draw Lines, and they ſhall be the true Hour-Lines. For the Stile take 63 deg. 28 min. from your Scale of Chords and ſet them from N to L, and draw the Line Z L for the Stile; The Subſtile is the Line N Z, or the Meridian of the place, as in *South Recliners*; but in theſe *North Recliners* the *North Pole* is always Elevated, and the Hours about Midnight left out: As in Figue XIV.

II. *By* Trigonometrical *Calculation.*

All the Calculation that is required in theſe Direct Reclining Plains, is only the *Height of the Pole above the Plain*, and the *Hour-diſtances from the Meridian.* For the Firſt, it is the Quantity of the Arch P R, Now from Z to R is 38 deg. 28 min. equal to the *Complement of the Latitude*, and Z R is 25 deg. equal to the *Reclination*, which added together make 63 deg. 28 min. And ſo much is the height of the *Pole* or *Stile* above the *Reclining Plain* E R W.

Stile's height 63 d. 28 m.

Hours from Noon.		Equinoctial Diſtances. D.	M.	Hour-Diſtances on the Plain. D.	M.
12		0	0	0	00
11	1	15	0	13	29
10	2	30	0	27	19
9	3	45	0	41	49
8	4	60	0	57	10
7	5	75	0	73	20
6		90	0	90	00

For the *Hour-Diſtances* from the *Meridian*, they are to be found by the general *Analogie* or *Proportion.*

As Radius 90 deg. 10.00000

To the Sine of 63 deg. 28 min. the Stile's Height; 9.95166

So is the Tangent of the firſt Equin. diſtance 15 deg. 9.42805

To the Tangent of 13 deg. 29 m. for the diſtance of 11 and 1 9.37971

The

The like muſt be done for all the reſt, and ſo ſhall you produce ſuch Numbers as are in the third Column of the Table.

The Stile muſt ſtand upon the *Meridian-Line* N Z, making an Angle of 63 deg. 28 min. therewith.

III. *The Third* Variety: North Reclining *more than the* Equinoctial.

I. *By* Projection.

Suppoſe a *North Plain* in the Latitude of 51 deg. 32 min. ſhould *Recline* from the *Zenith* 70 deg.

Firſt, Draw N S and E W at Right Angles in Z, and upon Z deſcribe a Circle, and therein *project* the *Sphere*. Which done, Take the *Plain's Reclination* 70 deg. out of your *Scale* of *Chords*, and ſet it upon the *Circle* from W to *a*, a Ruler laid from E to *a*, will cut the *Meridian* in R, (or 70 deg. taken out of the Scale of *Half Tangents*, will reach from Z to R alſo). Now having Three points E, R, and W, deſcribe it upon your Projection, the Center thereof will be in the Meridian Line N S, and will be diſtant from R, equal to the *Secant* of 20 deg: The Plain being drawn, find the *Pole* thereof, by taking 90 deg. of your Chords, and ſetting them from *a* to *b*, ſo a Ruler laid from E to *b*, ſhall cut the Meridian N S in Q the *Pole of the Reclining Plain*. But now to find the *Height* of P the Pole of the World, above the *Reclining Plain* E R W, Lay a Ruler upon E and P, it will cut the Circle in *d*, ſo ſhould *a d* be the height of the Pole above the Plain; which being above 90 deg, *viz.* 108 deg. 28 min. the Complement thereof to 180 deg. namely 71 deg. 32 min. is the Stile's height; which ſet from S to L, ſhall give you the point L, whereby to draw the Line of the Stile. *Figure* XV.

Next for the *Hour-Lines*. A Ruler laid to Q, the Pole of the Plain, and the reſpective points 1, 2, 3, *&c.* (where the *Hour-Circles* croſs the Plain) mark where the Ruler cuts the *Primitive Circle*, and there make marks or * * *; and from Z, if you draw Lines through thoſe * * *, they ſhall be the true *Hour-Lines* belonging to your *Reclining Plain*.

II. *By* Trigonometrical *Calculation.*

As in the other *Reclining Plains* which are direct *North* or *South*, there was no *Arithmetical Calculation* but only to find the *Height of the Pole above the Plain*, and the *Hour-Diſtances* from the *Meridian* of the Place, neither is there more in this.

For the firſt, (namely the Height of the *Pole* or *Stile* above the Plain) which is Repreſented by the Arch of the *Meridian* in the *Projection* by P R. Now from Z to P is 38 deg. 28 min. equal to the Complement of the Latitude, and Z R is 70 deg. equal to the Reclination, theſe two being added together make 108 deg. 28 min. but this cannot be the true height of the Pole above the Plain, for that can never exceed 90 degrees, but this Plain falling between the *Equator* and the *Horizon*, muſt needs have ſo much leſs than 90 deg. of Elevation, as the *Reclination* is more than the *Latitude*; therefore,

Stile's height 71 d. 32 m.					
Hours from Noon.		Equinoctial Distances.		Hour-Distances on the Plain.	
		D.	M.	D.	M.
12		0	0	0	00
11	1	15	0	14	16
10	2	30	0	28	43
9	3	45	0	43	30
8	4	60	0	58	41
7	5	75	0	74	14
6		90	0	90	00

If you add 38 deg. 28 min. the Complement of the Latitude, and 70 deg. the *Reclination*, together, the Sum will be 108 deg. 28 min. as before, whose *Complement* to 180 deg. is 71 deg. 32 min. and that is the true height of the Pole above the Plain: Or if you add Z A, 51 deg. 32 min. the Latitude, to R S 20 deg. (the Complement of the Plain's *Reclination*) the Sum of them will be 71 deg. 32 min. for the Height of the *Pole* or *Stile* above the *Plain*.

The Hour-Distances (now the height of the Stile is known) may be found by the *Common Analogy*.

As the Radius 90 deg.————10.00000

To the Sine of the Stile's height 71 deg. 32 min.——8.97704
So is the Tangent of 15 deg. to the first Equin. distance—9.42805

To 14 d. 16 m. the first Hour's distance from the Merid. 19.40805

And repeating this Work for all the Hours, you shall have such Distances as in the Third Column of the Table are set down.

The Stile must be erected upon the Meridian, and raised to an Angle of 71 d. 32 m. equal to the height of the Pole above the Plain.

CHAP. XVII.

How to draw the Hour-Lines *upon* South Declining Reclining *Plains.*

OF *South* direct *Reclining Plains*, there were *Three Varieties*, so are there as many of *South Recliners* which *Decline* also; For to any *Declination*, the *Plain* may *Recline* so, that it may pass through the Pole of the *World*. Or, *Secondly*, It may *Recline* so, that the *Plain* shall fall below the *Pole*, and so fall between the *Zenith* and the *Pole*. Also, *Thirdly*, It may so *Recline*, that the *Plain* shall pass between the *Pole* and the *Horizon*: Of all which *Varieties* I shall give particular *Examples*.

I. *The* First Variety: *Of* South Declining Reclining Plains, *The* Plains *passing* through *the* Pole.

I. *By* Projection.

Figure XVI. This Example shall be of a *South Plain*, *Declining* from the *South Eastward* 30 deg. and *Reclining* from the *Zenith* 34 deg. 32 min.

First,

First, Draw a Right Line A B, reprefenting the Bafis of your *Reclining Plain*, and crofs it with another Line C D, at Right Angles in the point Z.

Secondly, Upon Z, defcribe a Circle and in it from C towards E, (becaufe the Plain declines Eaftward) fet 30 deg. the *Declination* of the *Plain*, to N, and draw the Line N Z S for the *Meridian* of the *Place*, upon which, from Z to P, fet the Half Tangent of the Complement of the *Latitude* 38 deg. 28 min. and finifh the *Projection*: Which done,

Thirdly, Take the Half Tangent of the *Reclination* of the *Plain* 34 d. 32 m. and fet it from Z to R, upon the Line C D, fo have you three Points A, R, and B, by which to draw your Plain, whofe *Center* will be in the Line C D extended, and the *Secant* of 55 deg. 28 min. fet from R, will give the Center point: Alfo the Half Tangent of 55 deg. 28 min. being fet from Z will give you the point Q, for the *Pole* of the *Plain*; through which point Q, and P the *Pole* of the *World*, you muft (by the 12*th Problem* in the *Introduction*) draw the Arch of a *Great Circle*: And now feeing the Plain paffeth juft through the Pole of the World, the Pole hath no Elevation above it, and therefore the *Hour-Lines* muft be *parallel* one to the other. But before you can draw them, two things muft be found,

1. The *Diftance of the Meridian from the Horizon* P B.
2. The *Plain's Difference of Longitude*, the Angle Z P Q.

Both which by the *Projection* are thus found:

A Ruler laid from Q to P, will cut the Circle in *a*, and the diftance *a* B meafured upon the *Chords* will give 71 deg. 53 min. for the *Diftance of the Meridian from the Horizon*: And the Arch S *b*, meafured upon the *Chords*, will be 24 deg. 19 min. for the *Plain's Difference of Longitude*.

Thefe things found, the *Dial* muft be drawn *Geometrically*, not much differing from the direct *Eaft*, *Weft*, and *Equinoctial Dials*, as fhall be prefently fhewed. But First,

II. *By* Trigonometrical *Calculation*.

1. To find the *Diftance of the Meridian from the Horizon* P B.

By the interfection of the *Circles* of the *Sphere* with the *Plain*, you have conftituted a *Right-Angled Spherical Triangle* P R Z, Right Angled at R, in which there is given, (1.) The *Hypotenufe* Z P 38 deg. 28 min. the *Complement of the Latitude*. (2.) The *Angle* R Z P 30 deg. the *Plain's Declination*, and if you will, (3.) the fide R Z 34 deg. 32 min. the *Plain's Reclination*. To find the fide R P, the *Complement of the Meridian's diftance from the Horizon*: For doing whereof this is the Proportion.

As Radius 90 deg.	10.00000
To the Sine of P Z the Co-Latitude 38 deg. 28 min.	9.79383
So is the Sine of R Z P the Plain's Declination 30 deg.	9.69897
To the Sine of RP 18 deg. 7 min.	9.49280

The Complement whereof 71 deg. 53 min. is the Arch P B, the *Diftance of the Meridian from the Horizon*.

2. For

2. *For the Plain's Difference of Longitude* Z P Q.

As the Sine of P Z the Co-Latitude 38 deg. 28 min.	9.79383
Is to the Radius 90 deg.	10.00000
So is the Sine of Z R the Plain's Reclination 34 deg. 32 min.	19.75349
To the Sine of Z P R 65 deg. 41 min.	9.95966

Whose Complement 24 deg. 19 min. is the Angle Z P Q, the *Plain's Difference of Longitude.*

The Geometrical Projection of this Dial.

Figure XVII. First, Draw a Line at pleasure, as A Z B, representing the Horizontal Line of the Plain; Then, considering of what length you would have your *Stile* to be, answerable to the bigness of your *Plain*; suppose Z D, take that distance in your Compasses, and setting one foot in Z, with the other describe a Semicircle A C D B, upon which (by help of a Scale of Chords) set 71 deg. 53 min. the *distance of the Meridian from the Horizon*, from A to C, and draw the Line Z C E, for the *Substile.*

Secondly, Take 24 deg. 19 min. the *Plain's Difference of Longitude* and set it from C to D.

Thirdly, Through the point C, draw a Line F G, perpendicular to the *Substile* Z E; and another Line H I, at any distance parallel to F G.

Fourthly, Lay a Ruler from Z to D, it will cut the Tangent Line F G, in 12, through which point, draw the Line 12, 12 *Parallel* to the *Substile* Z E, for the *Hour-Line* of 12.

Fifthly, Divide the *Semicircle* A D B into 12 equal parts, at the points * * *, *&c.* beginning at D.

Lastly, Lay a Ruler unto Z, and upon every of the marks * * *, *&c.* and the Ruler will cut the Line F G, in the points 7, 8, 9, 10, 11, 12, 1, 2, through which points, draw Lines parallel to the *Substile* Z E, so is your *Dial* finished.

As for the *Stile*, it may be a straight *Pin* or *Wyre*, of the just length of the Line C Z, as K L, set perpendicular to the *Plain* upon any part of the *Substile*; whose point will give the Shadow.—— Or, it may be a *Plate* of *Brass* or *Iron*, of the same breadth with the Line Z C, which will shew the Hour by the Shadow of the side thereof.

II. *The* Second Variety: *Of South* Declining Reclining Plains; *The* Plain *passing between the* Pole *and the* Zenith.

I. *By the* Projection.

Figure XVIII. Our Second *Example* shall be of a *Plain Declining* from the *South Eastward* 30 deg. and *Reclining* from the *Zenith* 20 deg.

First, draw a Right Line A B, for the Base of the *Reclining Plain*, and another C D, perpendicular thereunto, for the *Vertical Line* of the *Plain*, crossing one another at Right Angles in Z.

Secondly

Secondly, upon Z deſcribe a Circle, and thereon ſet 30 deg. the *Declination* from A to E, and draw the Line E W for the *Prime Vertical Circle*, and at Right Angles to it the Line S P N for the *Meridian* of the Place, and now *Project* the *Sphere*, as hath been before taught.

Thirdly, Out of your Scale of Half Tangents, take 20 deg. the *Reclination* of the *Plain*, and ſet it from Z to H upon the Line C D; for the Plain: Alſo take 70 deg. and ſet them from Z to Q, for the Pole of the Plain; and having three Points *A*, H, and B, whereby to deſcribe your *Plain*, if you take the Secant of 70 deg. and ſet it from H; upon the Line C D extended, it ſhall give the Center whereby to deſcribe the *Reclining* Plain A H B.—— And now having found Q, the *Pole* of the *Plain*, you muſt through it, and P the *Pole* of the *World* (by the 12th Problem of the Introduction) deſcribe the *Arch* of a *Great Circle* Q R P.

Having proceeded thus far, the next thing to be done is to find the *Requiſites* belonging to this Plain, which in all *Declining-Reclining Plains* (excepting ſuch as paſs through the *Pole* of the *World*, or by the interſection of the *Meridian* and *Equinoctial*) are Four, *viz.*

1. The *diſtance of the* Meridian *and* Horizon	repreſen-ted by	O B
2. The *height of the* Pole *or* Stile *above the* Plain		P R
3. The *diſtance of the* Subſtile *from the* Meridian		O R
4. The Plain's *difference of* Longitude		O P R

And all theſe may be found by the *Projection:*

1. For O B: Lay a Ruler from Q to O, it will cut the Primitive Circle in *a*, the Diſtance from B to *a*, meaſured on a Scale of Chords, will be found to be 78 deg. 50 min. for the *Diſtance of the Meridian from the Horizon.*

2. For P R: You muſt firſt find the Pole of the *Great Circle* P R Q (as hath been taught already at the end of the Fourth Chapter hereof) which will be at *q* (always in ſome part of the Equinoctial Circle, namely, at the Interſection of the Equinoctial and the Plain): which found, Lay a Ruler from *q* to P, it will cut the Circle in *b*, and laid to R, it will cut the Circle in *c*, the diſtance *b c* meaſured on the *Chords*, will be found to be 13 deg. 49 min. for *The height of the Stile.*

3. For O R: A Ruler laid from Q to O, did cut the Circle in *a*; and laid from Q to R, it will cut the Circle in *d*; the diſtance *a d* will be found by the Scale of Chords to be 7 deg. 30 min. for the *Deflexion*, or *Subſtile's diſtance from the Meridian.*

4. For O P R: (The meaſure whereof upon the *Equinoctial* is Æ L) Lay a Ruler from P to L, it will cut the Circle in *e*, the diſtance N *e* meaſured, will be found 28 deg. 52 min. for *The Plain's difference of Longitude.*

The Requiſites being found, the next work will be to draw the *Hour-Lines*, which differs nothing from what is done in other Plains: Wherefore, Lay a Ruler upon Q (the *Pole* of the *Plain*) and upon the ſeveral points where the *Hour-Circles* of the *Projection* cut the *Plain* A H B, and where the Ruler cuts the *Primitive Circle* make marks or * * *: And from the Center R, Lines drawn through thoſe marks or * * * ſhall be the true *Hour-Lines.*—— The *Stile* muſt be Elevated above the *Subſtile* the quantity of the ſide P R, namely 13 deg. 49 min.

II. By Trigonometrical *Calculation.*

By the Interſection of the *Circles* of the *Sphere*, with the *Great Circles* belonging to this *Reclining Plain*, there are Conſtituted ſeveral *Spherical Triangles* ; but eſpecially *Two* : By the reſolving of which, all the fore-mentioned *Requiſites* may be attained : The two *Triangles* are H O Z, Right Angled at H, and O P R Right Angled at R.

I. *For the diſtance of the Meridian from the Horizon* B O.

This will be found in the Right Angled *Spherical Triangle* H O Z, in which is given, (1.) The Side H Z 20 deg. the *Plain's Reclination.* (2.) The Angle H Z O 30 deg. the *Plain's Declination* : To find the Side H O,

As Radius 90 deg.	10.00000
To the Sine of Z H 20 deg. the Reclination	9.53405
So is the Tangent of H ZO 30 deg. the Declination	9.76144
To the Tangent of H O 11 deg. 10 min.	9.29549

Whoſe Complement 78 deg. 50 min. is the Arch B O, the *Diſtance of the Meridian from the Horizon.*

2. *For the height of the Pole or Stile above the Plain* P R

This muſt be found in the Triangle P O R, but in it there is not yet enough given ; wherefore P O muſt be firſt found in the former Triangle H O Z. Thus,

As the Sine of H Z O 30 deg. the Declination	9.69897
To the Sine of H O 11 deg. 10 min.	9.28705
So is Z H O the Sine of 90 deg.	10.00000
To the Sine of O Z 22 deg. 47 min.	9.58808

Which ſubſtracted from Z P 38 deg. 38 min. there remains 15 deg. 41 min. for the ſide O P in the other Triangle O P R : And now ſeeing the two *Triangle* H O Z and P R O are a like, and the *Sines* of their *Hypotenuſes* and *Perpendiculars* are proportional, you may work with both *Triangles* together to find P R. For,

As the Sine of Z O 22 d. 47 m. *Hypot.*	in Trian. HOZ	9.58799
To the Sine of Z H 20 d. *Perpend.*		9.53405
So is the Sine of P O 15 d. 41 m. *Hypot.*	in Trian P O R	9.43188
To the Sine of P R 13 d. 49 min. *Perpend*		18.96593
		9.37794

3. *For the Diſtance of the* Subſtile *from the* Meridian O R.

In the Triangle P O R, where there is given the ſide P O 15 deg. 41 min. the ſide P R 13 deg. 49 min, And the *Right Angle* at R : To find O R.

As

Figure XIII.

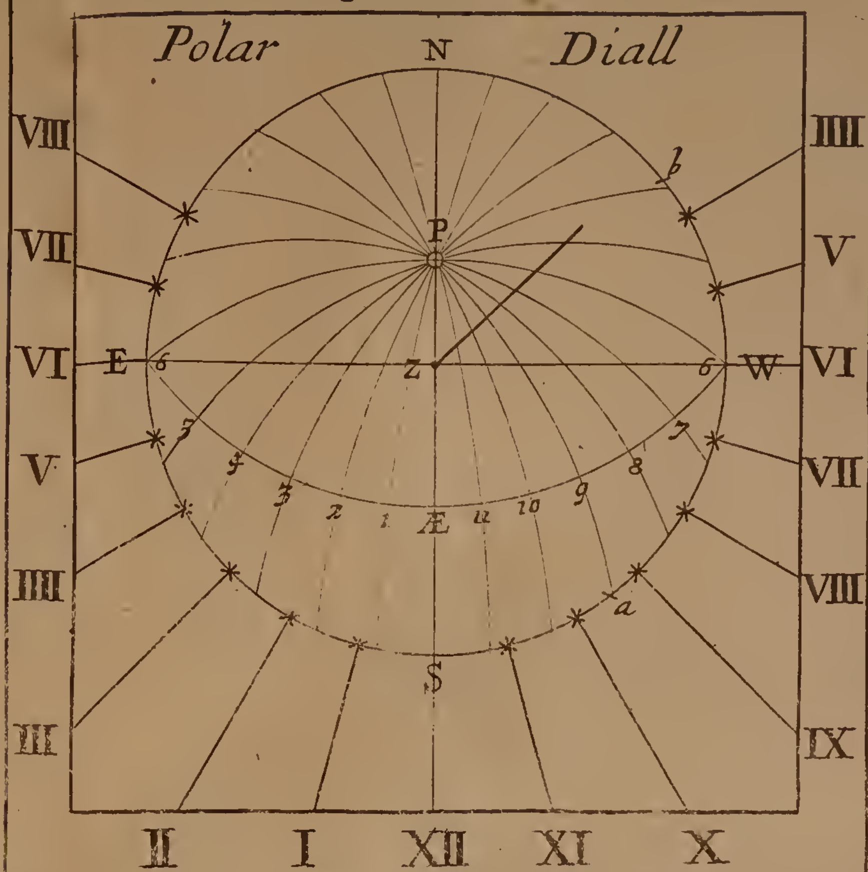


Figure XIIII.

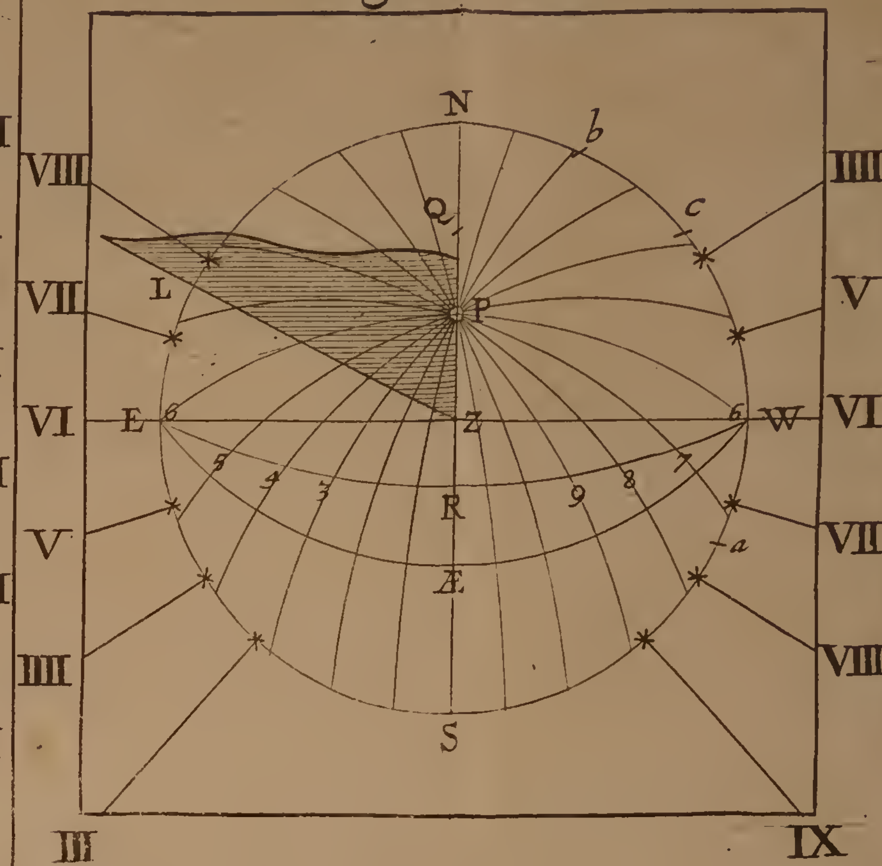


Figure XV.

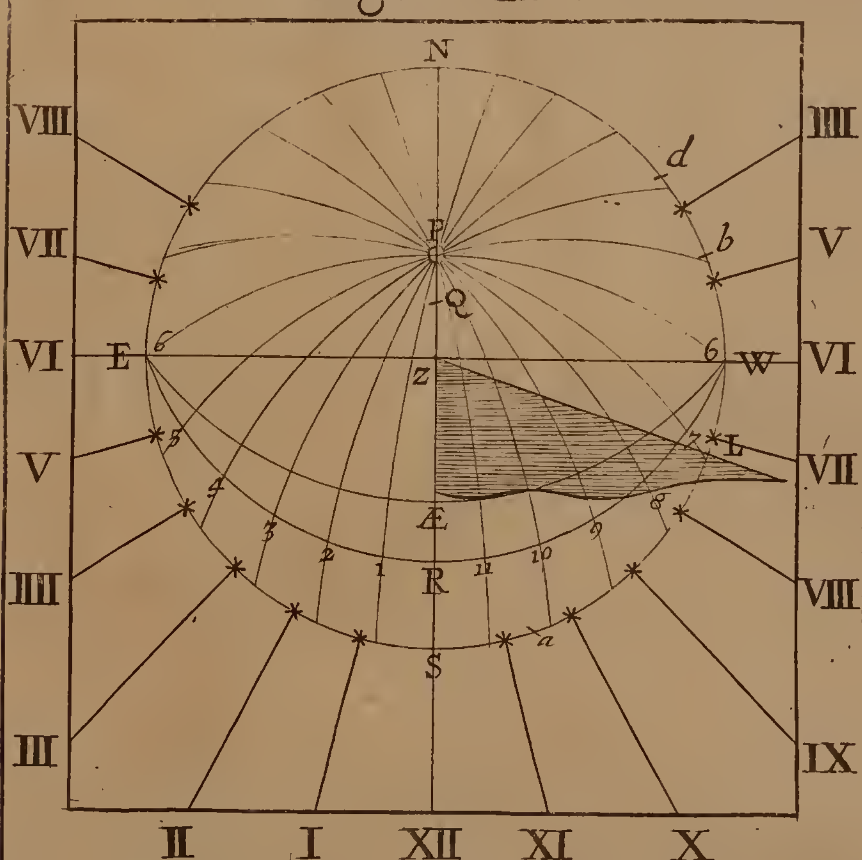


Figure XVI.

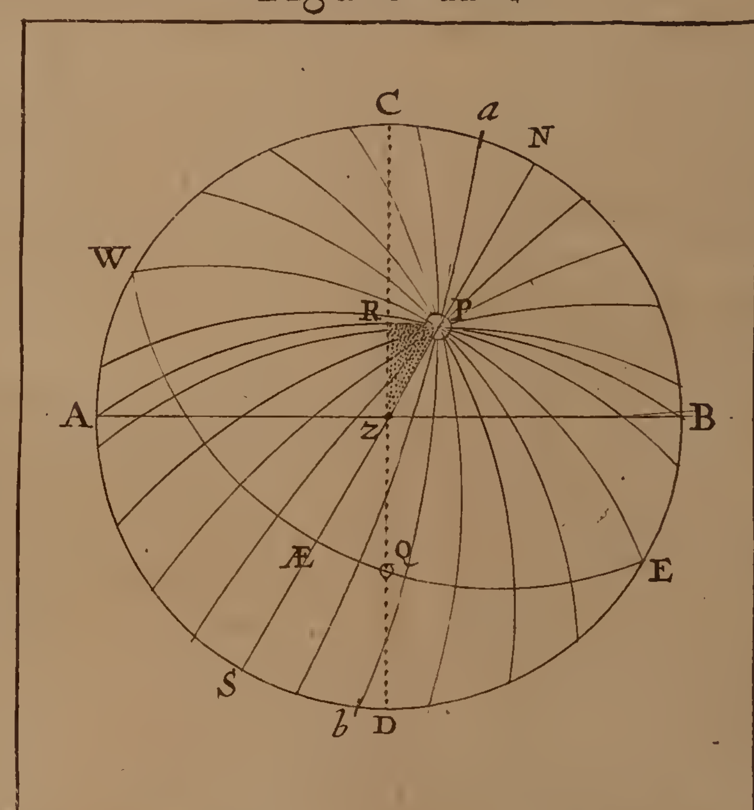


Figure XVII.

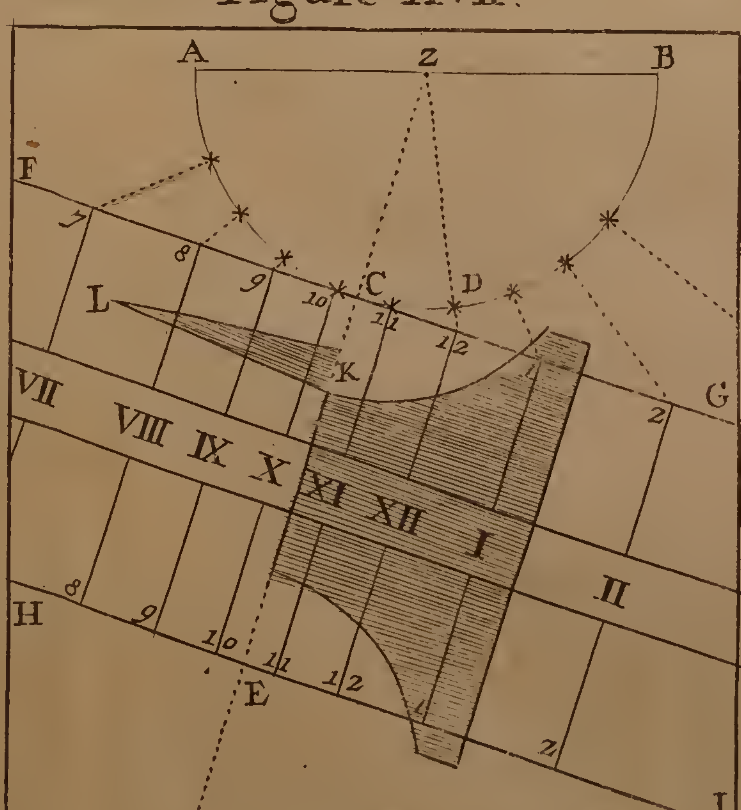
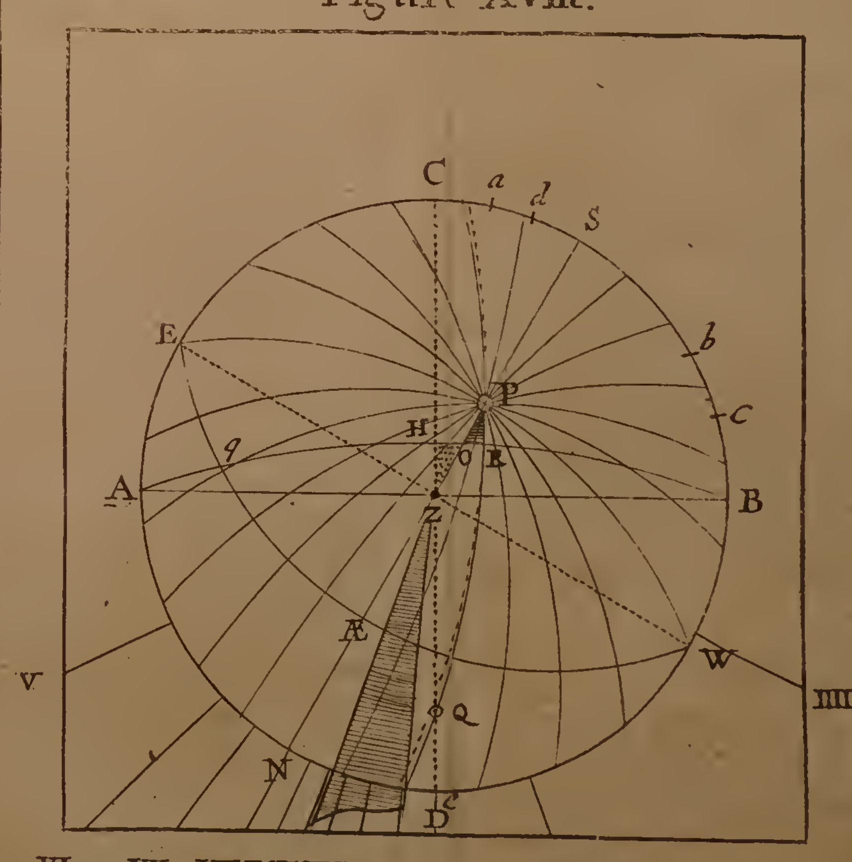


Figure XVIII.



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As the Co-Sine of P R 76 deg. 11 min.	9.98725
To the Radius P R O 90 deg.	10.00000
So is the Co-Sine of P O 74 deg. 19 min.	9.98352
To the Co-Sine of O R 82 deg. 30 min.	9.99627

Whose Complement 7 deg. 30 min. is the side O R, *The Substile's distance from the Meridian.*

4. *For the Plain's difference of Longitude* O P R.

As the Sine of P O 15 deg. 41 min.	9.43188
To P R O 90 deg.	10.00000
So is the Sine of R O 7 deg. 30 min.	9.11569
To the Sine of O P R 28 deg. 52 min.	9.68381

Which 28 deg. 51 min. is the *Plain's difference of Longitude.*

The next thing you are to seek, is the *Hour-Distances* upon the *Plain.*

The Plain's *Difference of Longitude* being 28 deg. 52 min. which is but *One Hour*, and 13 deg. 52 min. of the *Equinoctial* over; wherefore, The *Plain Declining Eastward*, the Stile must stand betwen the Hours of 10 and 11 in the Forenoon: Therefore, Prepare a *Table* and write down the Hours that the *Plain* is capable to receive, namely, from 5 in the Morning, till 4 in the Afternoon; and between the Hours of 10 and 11, where the *Substile* must stand, write the word *Sub-stile*, and under it write 13 deg. 52 min. which substracted from 15 deg. the remainer will be 1 deg. 8 min. which write over *Substile.* Then to these two Numbers, by the continual addition of 15 deg. (one *Equinoctial Hour's* distance) you shall produce such Numbers as are set down in the *second* Column of the *Table.* And now to find the *true Hour-distances* upon the *Plain*: Make use of the accustomed *Analogy.*

Latitude	51	32
Declination	30	00
Reclination	20	00
Dist. Mer. & Hor.	78	50
Stile's height	13	49
Deflection	7	30
Differ. of Long.	28	52

Hours from Noon		Equinoctial Distances. D.	M.	True Hour distances D.	M.
5	7	76	8	44	3
6		61	8	23	25
7	5	46	8	13	57
8	4	31	8	8	12
9	3	16	8	3	57
10	2	1	8	0	16
The		Sub-		stile.	
11	1	13	52	3	22
12		28	52	7	30
1	11	43	52	12	55
2	10	58	52	21	34
3	9	73	52	39	32
4	8	88	52	85	16

As

As the Radius 90 deg.	10.00000
To the Sine of the Stile's height 13 deg. 49 min.	9.37806
So is the Tangent of 76 d. 8 m. the Equinoctial diſtance of 5 or 7 a Clock.	10.60755
To the Tang. of 44 d. 3 m. the true diſt. of the Hours of 5 or 7 upon the Plain from the Subſt.	9.98561

And thus working for every *Hour*, you ſhall produce ſuch numbers as are in the third Column of the *Table*, which with the *Meridian*, *Subſtile*, *Stile*, or *Deflexion*, being ſet upon your *Plain*, your *Dial* is Finiſhed.

III. *The Third* Variety, *of* South Declining Reclining Plains: *The* Plain *paſſing between the* Pole *and the* Horizon.

I. *By* Projection.

Figure XIX. Let this Third *Example* be of a *South Plain Declining Eaſtward* 30 deg. and *Reclining* from the *Zenith* 55 deg.

Firſt, Draw a Right Line A B for the *Baſe* of your *Plain*, and croſs it with another Line C D, at right angles in Z, for the *Vertical Line* of the Plain.

Secondly, Upon Z deſcribe a Circle, and upon the Periſery thereof, ſet 30 deg. the *Plain's Declination*, from C to N, and draw the Line N Z S for the *Meridian* of the Place, Projecting the *Sphere* within the Circle.

Thirdly, Take 55 deg. the *Reclination*, from your *Scale* of *Half Tangents*, and ſet them from Z to F, for the point of your Plain, and ſet the Complement thereof 35 deg. from Z to Q, for the Pole of the *Plain*: And having three points A, F, and B, whereby to draw your *Reclining Plain*, the *Secant* Complement of the *Reclination* 35 deg. ſet from F upon the Line F D, will give you the *Center* whereby to deſcribe it.

Fourthly, Through P the *Pole* of the *World*, and Q the *Pole* of the *Plain*, draw the Arch of a *Great Circle* R P Q (by the 13 Prob. of the Introduction) and find the *Pole* thereof at *q* in the *Equinoctial Circle*.

Fifthly, You muſt find theſe *Requiſites*,

1. The *Diſtance of the* Meridian *from the* Horizon	repre-ſent-ed by	O B
2. The *Height of the* Pole *or* Stile *above the* Plain		P R
3. The *Diſtance of the* Subſtile *from the* Meridian		R O
4. The Plain's *Difference of Longit.* RPO *or*		ÆP Q.

All which may be found by the *Projection*, in this manner:

1. For O B: Lay a Ruler from Q to O, it will cut the Circle in *a*, and B *a* meaſured upon the *Chord*, will give 64 deg. 41 min. for the *Diſtance of the Meridian from the Horizon.*

2. For P R: Lay a Ruler from *q* to P, it will cut the Circle in *b*: alſo, a Ruler laid from *q* to R, will cut the Circle in *c*, the diſtance *b c* being 19 deg. 25 min. is the *Height of the* Pole *or* Stile *above the* Plain.

3. For

3. For R O: A Ruler laid from Q to O, did cut the Circle in *a*, and Laid from Q to R, it will cut it in *d*, the diſtance *a d*, 6 deg. 2 min. is the *Deflexion*, or *The* Subſtile's *diſtance from the* Meridian.

4. For R P O, (or rather Æ P Q) whoſe meaſure upon the Equinoctial is Æ L, a Ruler laid from P to L, will cut the Circle in *e*, and S *e* meaſured upon the *Chord*, will be 17 deg. 38 min. for the *Angle between the* Meridian *of the* Place, *and the* Meridian *of the* Plain, which is the *Plain's Difference of Longitude*.

The *Requiſites* thus obtained, The *Hour-lines* are to be drawn as in other *Plains*, by laying a Ruler to Q, and to the ſeveral Points where the *Hour-Circles* croſs the *Plain*; and where the Ruler cuts the *Primitive Circle*, make marks or * * *, through which Points, or * * *, from the Center Z, draw Lines, and they ſhall be the true *Hour-lines* proper for your *Plain*.

II. *By* Trigonometrical *Calculation.*

The *Triangles*, by the reſolution whereof the *Requiſites* may be found, are the Triangles O F Z, R O P, and O N B.

1. *For the Diſtance of the Meridian from the Horizon* B O.

In the Triangle O F Z, you have given (1) The Side F Z, the *Plain's Reclination* 55 deg. (2) The Angle F Z O, the *Plain's Declination*; and (3) The Right Angle at F.

As The Radius O F Z 90 deg.	10.00000
Is to the Sine of F Z, the Plain's Reclination, 55 deg.	9.91336
So is the Tangent of C N, the Plain's Declination, 30 deg.	9.76144
To the Tangent of F O 25 deg. 19 min.	9.67480

Whoſe Complement is O B 64 deg. 41 min. the *Diſtance of the Meridian from the Horizon*.

2. *For the Height of the Pole or Stile above the Plain* P R.

This ſhould be found in the Triangle R O P, but there is not enough given; wherefore, in the Triangle O N B, you muſt ſeek the Side N O, thereby to come to the Side O P, thus,

As the Sine of O B N 90 deg.	10.00000
Is to the Sine of B O 64 deg. 41 min.	9.95615
So is the Sine of N B O 35 deg.	9.75859
To the Sine of N O 31 deg. 14 min.	9.71474

This N O 31 deg. 14 min. taken out of N P, 51 deg. 32 min. leaves 20 deg. 18 min. for P O.

And now becauſe the *Hypotenuſes* and *Baſes* of the *Triangles* O N B and R P O are proportional, you may deal with them *both* joyntly to find P R: For,

R As

As the Sine of B O 64 d. 41 m. Hypot. } in Triang. NOB 9.95615
To the Sine of N B 60 deg. Perpen. } 9.93753

So is the Sine of P O 20 d. 18 m. Hypot. } in Triang. ROP 9.54025
To the Sine of R P 19 d. 25 m. Perpen. } 19.47778
9.52163

3. *For the distance of the* Substile *from the* Meridian R O.

As the Co-Sine of R P 19 deg. 25 min.	9.97457
To the Sine of P R O Radius 90 deg.	10.00000
So is the Co-Sine of P O 20 deg. 18 min.	9.97215
To the Co-Sine of R O 6 deg. 2 min.	9.99758

Which 6 deg. 2 min. is the *Deflexion*, or *Substile's distance from the Meridian.*

4. *For the* Plain's *Difference of Longitude* P R O.

As the Sine of P O 20 deg. 18 min.	9.54025
To P R O Radius	10.00000
So is the Sine of R O 6 deg. 2 min.	9.02163
To the Sine of R P O 17 deg. 38 min.	9.48138

Which 17 deg. 38 min. is the *Plain's difference of Longitude.*

Latitude	51	32
Declination	30	00
Reclination	55	00
Dist. Mer. & Hor.	64	41
Stile's height	19	25
Deflection	6	2
Differ. of Long.	17	38

Hours from Noon		Equinoctial Distances. D.	M.	True Hour distances D.	M.
5	7	87	22	82	7
6		72	22	46	17
7	5	57	22	27	26
8	4	42	22	16	52
9	3	27	22	9	46
10	2	12	22	4	10
		Sub-		stile.	
11	1	2	38	0	53
12		17	38	6	2
1	11	32	38	12	1
2	10	47	38	20	1
3	9	62	38	32	42
4	8	77	38	56	35

This 17 deg. 38 min. is but one Hour, and 2 deg. 38 min. of the Equinoctial over, it denotes (the Plain declining *Eastward*) that the *Stile* must stand between the Hours of 10 and 11, a small distance beyond 10: Wherefore, prepare your *Table*, and set down all the Hours the *Plain* is capable to receive, as from 5 in the morning till 4 in the Afternoon; and between the Hours of 10 and 11 write *Sub-stile*, and under it, the 2 deg. 38 min. remaining, which substract from 15 deg. and the remainder 12 deg. 22 min. set over *Sub-stile*, and by the continual addition of 15 deg. to these numbers above and below the word *Sub-stile*; you shall produce such Numbers as those in the Second *Column* of this *Table* are.

Now for the *Hour-Distances* upon the *Plain*, they are found by the usual *Canon*, viz.

As the Radius 90 deg.	10.00000
To the Sine of the *Stile's* height 19 deg. 25 min.	9.52171
So is the Tan. of 42 d. 22 m. Eq. dist. for 8 and 4 a Clock	9.96002
To the Tangent of 16 d. 25 m. the true dist. of those Hours upon the *Plain* from the *Substile*	9.48173

And so for all the rest of the Numbers in the *Table*: And having found all the *Requisites*, you may by a *Scale of Chords* transfer them and the *Hour-distances* also from this *Table* to your *Plain*.

CHAP. XVIII.

How to draw the Hour-Lines *upon* North Declining Reclining Plains.

As there were Three *Varieties* in *South Reclining Plains* which *Decline*, so are there as many in *North Decliners Reclining*; for to any *Declination* a *Reclination* may be fitted, that the *Plain* shall pass by the Intersection of the *Meridian* with the *Equinoctial Circle*.—— Or the *Reclination* may be such, that the *Plain* shall pass beween the *Zenith* and the *Equator*.—— Or, it may recline so, that the *Plain* shall pass between the *Equator* and the *Horizon*: *Examples* of all these *Varieties* follow in order.

I. *The* First Variety: Of North Declining Reclining Plains, *The* Plain *passing* through *the Intersection of the* Meridian *with the* Equinoctial.

I. *By the Projection.*

Our First *Example* shall be of a *North Plain declining Westward* 60 deg, and *Reclining* from the *Zenith* 32 deg. 11 min *Figure* XX.

First, Draw a Line A B, representing the *Base* of your *Reclining Plain*, and another at right angles thereto, as C D, for the *Vertical* Line of the *Plain*, crossing each other in Z.—— Upon Z, describe a Circle, and upon the Periferie thereof, set 60 deg. (the Plain's Declination) from C towards B, at N; and from D towards W, at S, because the Plain Declines Westerly; and draw the Line N S for the *Meridian* of the *Place*, and so finish your *Projection*.

Secondly, Take 32 deg. 11 min. from your *Scale* of *Half Tangents*, and set it from Z to G, upon the Line C D; so shall G be the *point* in the *Vertical Line*, through which the *Plain* must pass. Also, take the *Half Tangent* of 57 deg. 49 min. the Co-Reclination, and set it from Z to Q, upon the Line C D also; so shall Q be the *Pole* of the *Plain*: And the *Secant* of 57 deg. 49 min. the Complement of the Reclination, being set from G, upon the Line D C extended, will give the *Center* whereby to describe the *Plain* A G B.

Thirdly,

Thirdly, Through P, the *Pole* of the *World*, and Q the *Pole* of the *Plain*, describe an Arch of a *Great Circle* (by the 13th Problem of the *Introduction*) which you shall find to be the same with the *Hour-Circle of Six*, and therefore the *Hour-Line of Six* will be the *Substilar line* of the *Dial*, and the *Pole* of this *Circle* (by the latter part of the Fourth Chapter hereof) will be found at Æ, the very point of the Intersection of the *Meridian* with the *Equinoctial*.

Fourthly, The *Requisites* belonging to this *Plain* are Four; as in *South Decliners Reclining*; viz.

1. *The Distance of the Meridian from the Horizon,*	represented by	A Æ.
2. *The Height of the Pole or Stile above the Plain,*		P R.
3. *The Substile's Distance from the Meridian,*		Æ R.
4. *The Plain's Difference of Longitude,*		Q P Æ.

All which by the *Projection* may be thus easily found.

1. For A Æ, Lay a Ruler from Q to Æ, it shall cut the *Plain* in *a*, the Distance from A to *a*, measured upon a *Scale* of *Chords*, will be 47 deg. 18 min. for the *Distance of the Meridian from the Horizon.*

2. For P R, Lay a Ruler from *q* to R, it will cut the Circle in *b*, the Distance N *b*, measured upon a *Scale* of *Chords*, will give 42 deg. 52 m. for *the Height of the Pole or Stile above the Plain.*

3. For Æ R, A Ruler laid from Æ to R, did cut the Circle in *b*, and laid from Æ to Q, it will cut the Circle in *c*, the Distance from *b* to *c* will be found to be just 90 deg. for *the Substile's Distance from the Meridian.*

4. For Q P Æ, or Æ P R, that is also 90 deg. for *the Plain's Difference of Longitude.* For it is obvious from the *Projection*, that all the *Sides* of the *Triangle* Q Æ R, are all *Quadrants*, and all the *Angles* by consequence *Right Angles.*

The *Requisites* being thus found, the Hour-Distances may be found as in other Plains, by laying a Ruler to Q, and the several Points where the *Hour-Circles* cross the *Plain*, and where the Ruler cuts the *Primitive Circle*, make marks or * * *, and through them, from Z, draw right Lines for the Hours.

In this *Dial* the Hour-Line of 6 is the *Substile*, and the Hour-Line of 12 is 90 deg. distant from it, so that they cross each other at Right Angles, as in all Direct Plains they do. And this *Dial* is no other than an *Horizontal Dial* for the *Latitude* of 42 d. 52 m. if you change the naming of the Hours, calling 6-12 and 5-11, *&c.*

II. *By* Trigonometrical *Calculation*.

To find the Requisites.

1. *For* A Æ, *the Distance of the Meridian from the Horizon.*

In the Triangle Z G Æ, right-Angled at G, there is given (1) Z G the *Plain's Reclination* 32 d. 11 m. (2) the Angle Æ Z G the *Plain's Declination* 60 d. (3) the right Angle Z G Æ, by which you may find Æ G. Thus,

As

Fig. I.

Fig. II.

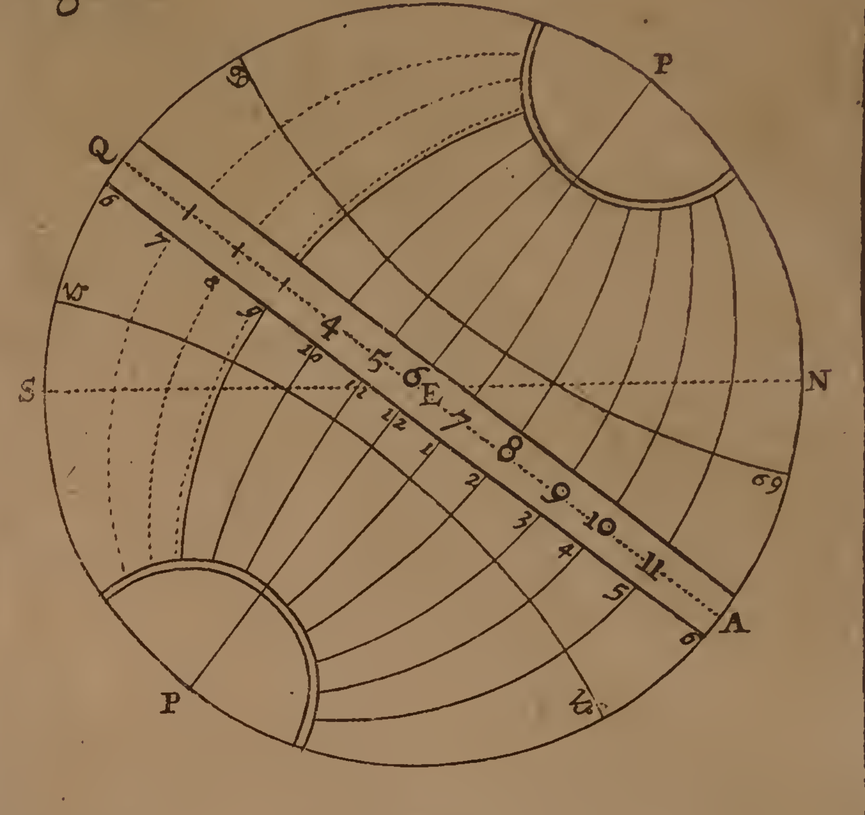


Fig. III.

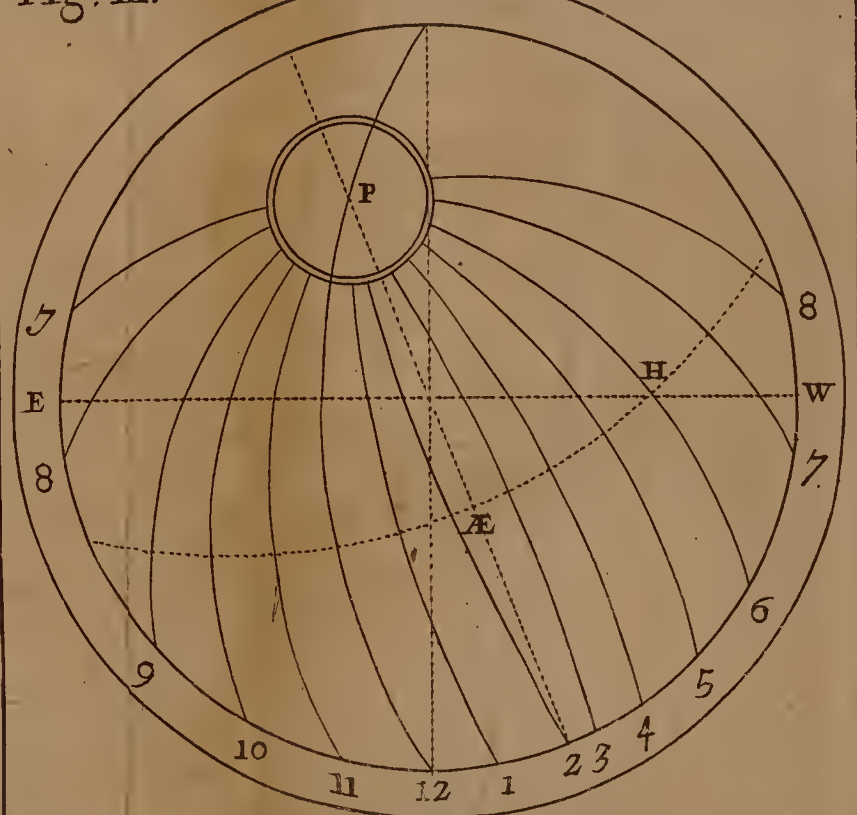


Fig. IV.

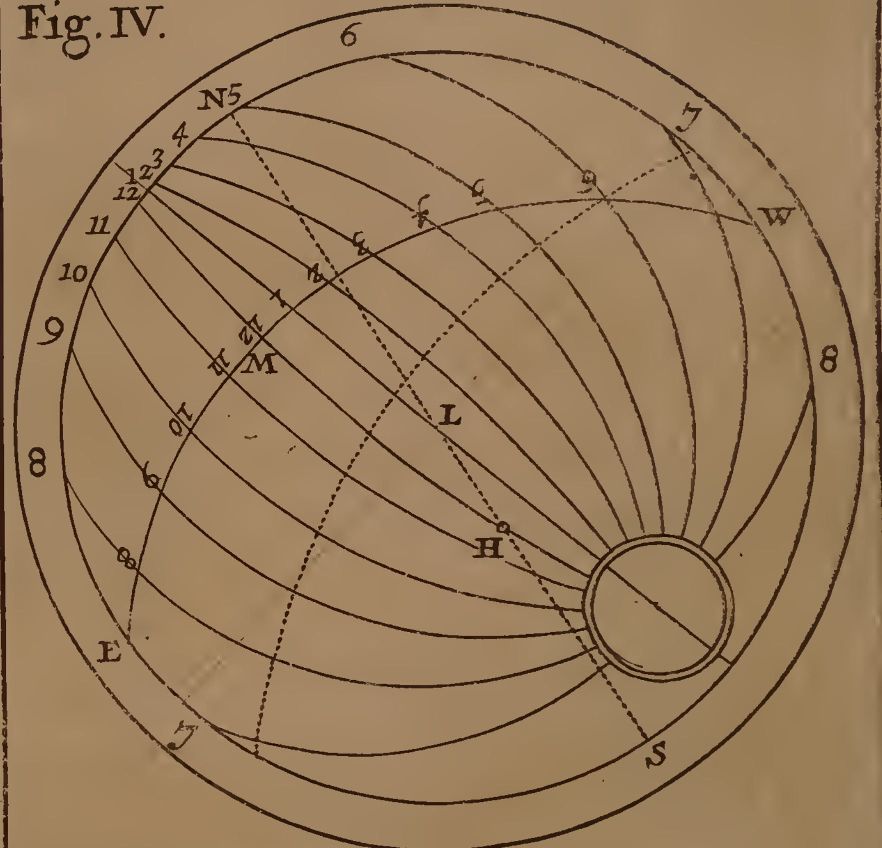


Fig. V.

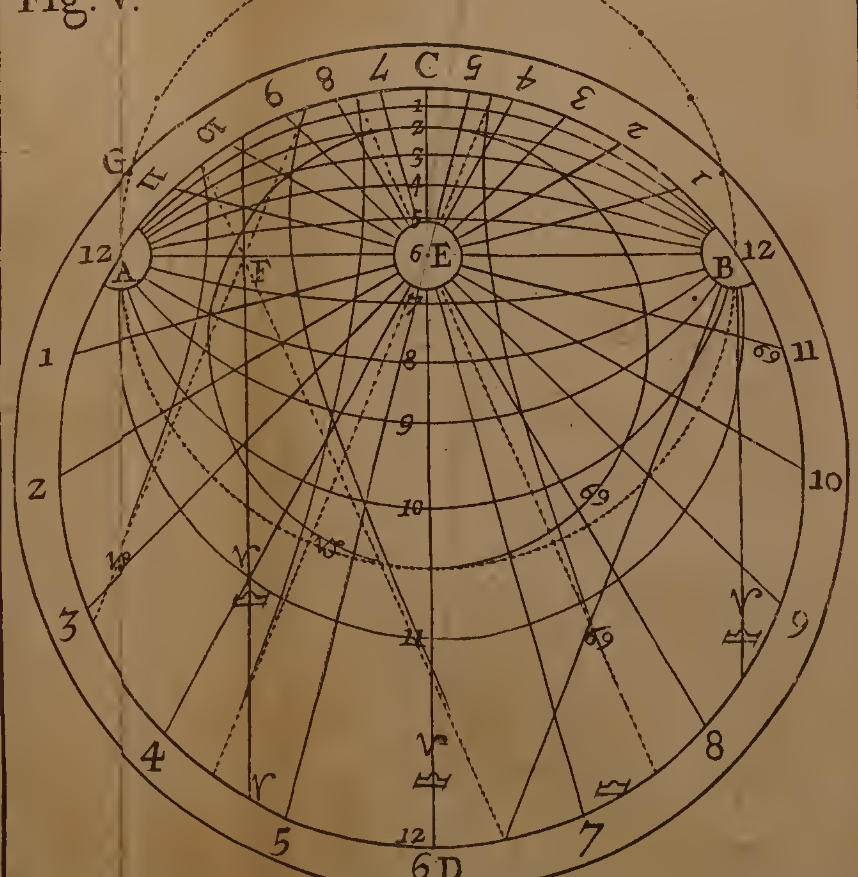
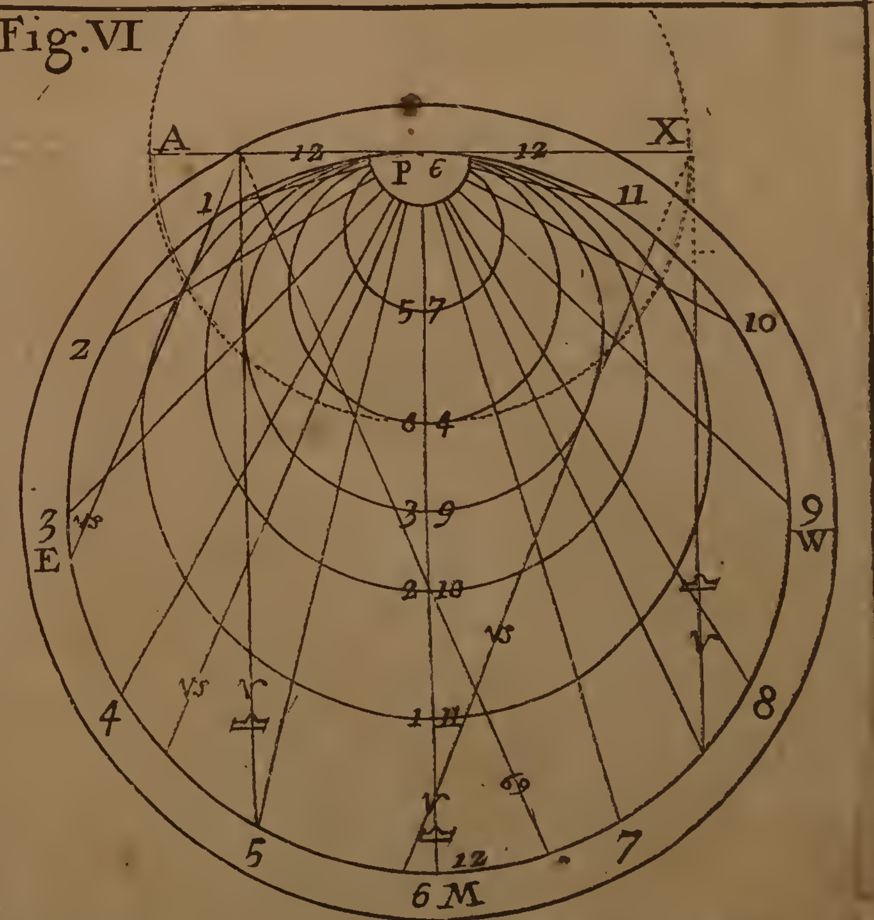


Fig. VI



Against ye end of ye Eighth Tractate Page 64 to fold out.

As Radius 90 deg.	10.00000
To the Tangent of Æ Z G 60 d. the Declination	10.23856
So is the Sine of Z G 32 d. 11 m. the Reclination	9.72642
To the Tangent of Æ G 42 d. 42 m.	9.96498

Whose Complement 47 d. 18 m. is *the Distance of the Meridian from the Horizon.*

2. *For* P R *the height of the Pole above the Plain.*

In the Quadrantal Triangle P Æ R,

As the Sine of Æ G 42 d. 42 m.	9.83133
To Radius Æ R 90 deg.	10.00000
So is the Tangent of Z G 32 deg. 11 min.	9.79887
To the Tangent of P R 42 d. 52 m.	9.96754

Which is *the height of the Pole or Stile above the Plain*

3. and 4. For the other two *Requisites*, the *Distance* of the *Substile* from the *Meridian* R Æ, and the *Plain's Difference* of *Longitude* Q P Æ or Æ P R, they are either of them 90 deg. as is evident in the *Projection.*

And for the *Hour-Distances* they are calculated as the Hour-Distances for an *Horizontal Dial*, wherefore prepare a *Table* as is here done, setting the *Equinoctial Distances* against their proper *Hours*; And then by the general *Analogy* or *Proportion* say,

As Radius 90 deg.	10.00000
To the Sine of 42 d. 52 min. the Stile's height	9.83270
So is the Tang. of 15 d. &c.	9.42805
To the Tangent of 10 d. 20 m.	9.26075

For the two first Hours from Six, the Substile of 5 and 7 on either side; and so for all the rest, as in the *Table.*

Latitude	51	32
Declination N.	60	00
Reclination	32	11
Dist. Mer. & Hor.	47	18
Stile's height	42	52
Deflection	90	00
Differ. of Long.	90	00

Hours from Noon.		Equinoctial Distances. D.	M.	True Hour-Distances D.	M.
6		0	00	0	00
7	5	15	00	10	20
8	4	30	00	21	27
9	3	45	00	34	14
10	2	60	00	49	41
11	1	75	00	68	30
12		90	00	90	0

II. *The*

II. *The* Second Variety: *of* North Declining Reclining *Plains, where the* Plain *passeth between the* Zenith *and the* Equator.

I. *By the* Projection.

Figure XXI. Let this Second *Example* be of a *North* Plain, *declining Westward* 60 deg. and Reclinign from the *Zenith* 16 degrees.

First, draw a right Line A B, for the *Base* or *Horizontal Line* of your *Reclining Plain*, and at right Angles thereunto another C D, for the *Vertical Line* of the *Plain*, crossing in Z: — Upon Z describe a Circle, and upon it from C to N, and from D to S, set the Plain's *Declination* 60 d. drawing the Line N S for the *Meridian* of the *Place*:— Upon which set off the Pole of the World at P, and in the Circle project the Sphere.

Secondly, Take the *half Tangent* of 16 deg. the Plain's *Reclination*, and set it from Z to H, so shall H be the *Point* in the *Vertical Line* C D, through which the *Reclining Plain* must pass: — Also the *half Tangent* of 74, the *Complement* of the Plain's *Reclination*, being set from Z upon the Line CD, shall give the Point Q, for the Pole of the Plain —— And so have your three Points, namely, A, H, and B, through which the *Reclining Plain* must pass. The *Secant* of the *Co-Reclination*, being set from H, upon the Line C D extended, will give you the *Center* whereby to describe it.

Thirdly, Through P the *Pole of the World*, and Q the *Pole* of the *Plain*, draw the Arch of a *Great Circle* (by the 13th Prob. of the *Introduction*) and find the *Pole* thereof, which will be at *q*, where the *Plain* crosseth the *Equinoctial* Circle.

Fourthly, Find the Four *Requisites* relating to this *Plain*, viz.

1. *The Distance of the Meridian from the Horizon,*	represented by	A O.
2. *The height of the Pole or Stile above the Plain,*		P R.
3. *The Deflexion or Substile's Distance from the Merid*		R O.
4. *The Plain's Difference of Longitude,*		O P R.

All which by the *Projection* may be thus found.

1. For A O, A Ruler laid from Q to O, will cut the *Primitive Circle* in *a*, and the Distance A *a*, 64 deg. 29 min. is *the Meridian's* Distance from the *Horizon*.

2. For P R, a Ruler laid from *q* to R, will cut the Circle in *b*, and laid from *q* to P, it will cut the Circle in *c*, the distance between *c* and *b*, 30 d. 59 m. is *the Height* of the *Pole* or *Stile* above the *Plain*.

3. For R O, A Ruler laid from Q to O, did cut the Circle in *a*, and now laid from Q to R, it will cut the Circle in *d*, the distance *a d*, 64 deg. 26 min. is the *Deflexicn* or *Substile's* Distance from the *Meridan*.

4. For O P R, A Ruler laid from P to *e* (where the Arch of the *Great Circle* Q P R crosseth the *Equinoctial Circle*) shall cut the Circle in *h*, the Distance S *h* 76 deg. 10 min. is the *Plain's Difference* of *Longitude*.

Fifthly

Fifthly, For the *Hour-Distances*, they are found in all respects as in other *Plains*, by laying a Ruler to Q, and the several Points where the *Hour-Circles* cross the *Plain* B H A, and where the Ruler cuts the *Primitive Circle* make marks or * * *, and from Z, through those marks, Lines drawn shall be the Hour-Lines.

II. By Trigonometrical *Calculation*.

The first thing to be done is to find the Requisites.

1. *For* A O, *the* Distance *of the* Meridian *and* Horizon.

In the Right Angled *Spherical Triangle* Z H O, Right Angled at H, there is given. (1) The Side Z H 16 deg. the *Reclination*. (2) The Angle H Z O 60 deg. the *Declination*, (3) The *Right Angle* at R. — To find the Side A O.

As Radius R 90 deg.	10.00000
To the Sine of Z H 16 deg.	9.44034
So is the Tangent of H Z O 60 deg.	10.23856
To the Tangent of H O 25 deg. 31 min.	9.67890

Whose Complement AO 64 deg. 29 min. is the *Distance* of the *Meridian* from the *Horizon*.

2 *For* P R, *which must be found in the* Triangle P R O.

In which there is not yet enough given, wherefore you must get the Side P O, by resolving the Triangle H O Z. Thus,

As the Sine of H Z O the Declination 60 deg.	9.93753
Is to the Radius 90 deg. *H*	10.00000
So is the Sine of H O (the Arch before found) 25 d. 31 m.	9.63425
To the Sine of Z O 29 deg. 50 min.	9.69672

Unto which 29 deg. 50 min. if you add Z P 38 deg. 28 min. the sum will be 68 d. 18 m. and so have you the whole side P O.

Now the two Triangles, O Z H, and R O P, being proportional, the Side P R may be thus found,

		9.69672
As the Sine of O Z 29 d. 50 m. *Hyp.*	in Trian. Z H O	
To Sine of H Z 16 deg. *Per.*		9.44034
So is Sine of O P 68 d. 18 m. *Hyp.*	in Trian. P R O	9.96807
To Sine of P R 30 d. 59 m. *Per.*		
		19.40841
		9.71164

Which 30 deg. 59 min. is the *Height* of the *Pole* or *Stile* above the *Plain*.

3. *For*

3. *For* O R *the* Deflection *or* Substile's Distance *from the* Meridian.

In the two former Triangles the *Sines* of the *Bases*, and the *Tangents* of the *Perpendiculars* being *Proportional*, work thus,

		9.45749
As the Tangent of Z H 16 deg. *Perpend.*	in Trian. Z H O	
Is to the Sine of H O 25 d. 31 m. *Base*		9.63425
So is the Tang. of P R 30 d. 59 m. *Perp.*	in the Tri. Z R O	9.77849
To the Sine of R O 64 d. 26 m. *Base*		
		19.41274
		9.95525

Which 64 deg. 26 min. is the *Deflection*, or *Substile's* Distance from the *Meridian.*

4. *For* O P R, *the* Plain's Difference *of* Longitude.

As the Sine of P R 30 deg. 59 m. the Stile's Height	9.71163
To the Sine of 90 deg. the Radius	10.00000
So is the Tangent of R O 64 deg. 26 min. the Deflexion	10.32020
	20.32020
To the Tangent of R P O 76 deg. 10 min.	10.60857

Which 76 deg. 10 min. is the *Plain's Difference* of *Longitude.*

5. *For the* Hour-Distances, *the* Plain's Difference *of* Longitude *being* 76 *deg.* 10 *min.*

Latitude	51	32
Declination	60	00
Reclination	16	00
Dist. Mer. & Hor.	64	29
Stile's height	30	59
Deflection	64	26
Differ. of Long.	76	10

Hours from the Substile.		Equinoctial Distances. D.	M.	Hour distances from the Substile. D.	M.
1	11	88	50	87	44
2	10	73	50	60	37
3	9	58	50	40	24
4	8	43	50	26	18
5	7	28	50	15	49
6	6	13	50	7	13
The		Sub-		stile.	
7	5	1	10	0	36
8	4	16	10	8	29
9	3	31	10	17	18
10	2	46	10	28	12
11	1	61	10	43	5
12	12	76	10	64	26

In this Distance is contained five compleat Hours, and 1 deg. 10 min. more, wherefore the Stile must stand between the fifth and sixth Hours from the *Meridian.* Prepare therefore a *Table* as here is done, and write down all the *Hours*, and between the Hours of 5 and 6, or 6 and 7 (which are all one, according as the Plain declines Eastward or Westward) write *Substile*; and under it, the remainder 1 d. 10 m. against 7 and 5, which substract from 15 deg. and there will remain 13 deg. 50 min. which write over *Substile* against the hours of 6 and 6. And so, by the continual addition of 15 deg. to the numbers next above and below *Substile*, you shall produce such numbers as this *Table* affords in the second Column thereof: from which numbers, which are *Equinoctial distances*, the *True hour-distances* upon the *Plain* may be collected by this *Proportion.*

As

As Radius 90 deg.	10.00000
To the Sine of 30 deg. 59 min. the Stile's height	9.71163
So is the Tangent of 88 deg. 50 min. the first Equi. Dist.	11.69112
To the Tangent of 87 deg. 44 min.	11.40275

Which is the true Hour-Distance of the Hours of One and Eleven upon the Plain from the *Substile*: and so doing for all the rest, you shall produce such numbers as the third *Column* of the *Table* affordeth, which may be transferred from this *Table* by help of a *Scale* of *Chords*; and so is your Dial finished.

III. *The Third* Variety *of* North Declining Reclining Plains, *where the* Plain *passeth between the* Equator *and the* Horizon.

I. *By the Projection.*

Figure XXII

OUr Third and Last *Example* shall be of a *North Plain*, *Declining Eastward* 60 deg. and *Reclining* from the *Zenith* 54 deg.

First, Draw a right Line A B for the *Horizontal Line*, or *Base* of the *Reclining Reclining Plain*, and cross it at Right Angles in Z, with another Right Line C D, for the *Vertical Line* of the *Plain*.—— Upon Z, describe a Circle, and upon it, from C to N, and from D to S, set 60. deg the *Declination* of the *Plain*, and draw the Line S N for the *Meridian* of the *Place*, upon which set off P the *Pole*, and Æ the *Equinoctial's* intersection therewith; and *Project* the *Sphere* within the *Circle* W N E S, as formerly.

Secondly, Take the *half Tangent* of 54 deg. the *Plain's Reclination*, and set it from Z to F, so shall F be the Point in the *Vertical Line* C D, through which the *Reclining Plain* must pass. —— Also the *Half Tangent* of 35, the *Co-Reclination* of the *Plain*, set from Z upon the *Vertical Line* C D, shall give Q for the *Pole* of the *Plain*.—— And now you have three Points, A, B, and F, whereby to draw the *Reclining Plain*, and the *Secant* of 36 deg. set from F upon the Line C D, will give the *Center* whereby to describe it.

Thirdly, Through P and Q, the *Pole* of the World, and the *Pole* of the *Plain* (by the 12 *Problem* of the *Introduction*) draw the Arch of a *Great Circle* Q P R, and find the *Pole* thereof, which will be at *q* the intersection of the *Plain* with the *Equinoctial* Circle.

Fourthly, You must next find the Four *Requisites* belonging to this *Plain*, viz.

1. *The Distance of the Meridian from the Horizon,*	represented by	A O.
2. *The Height of the Pole or Stile above the Plain,*		P R.
3. *The Deflection or Substile's Dist. from the Merid.*		O R.
4. *The Plain's Difference of Longitude,*		O P R.

1. For

1. For A O, A Rule laid from Q to O, will cut the Circle in *a*, and the Distance *A a* measured upon the *Scale of Chords*, will be 35 deg. 31 min. for the *Distance* of the *Meridian* from the *Horizon*.

2. For P R, A Ruler laid from *q* to P will cut the Circle in *b*, and laid from *q* to R it will cut it in *c*, and the Distance *b c* measured upon the *Chords* will be 54 deg. 43 min. for the *Height* of the *Pole* or *Stile* above the *Plain*.

3. For O R, A Ruler laid from Q to O, did cut the Circle in *a*, and laid from Q to R, it will cut it in *e*, so the Distance *a e* is 123 deg. 19 min. for O R, whose *Complement* to 180 deg. is 56 deg. 41 min. for R X; the *Distance* of the *Substile* from the *Meridian*.

4. For O P R (or rather its Complement O P Q, equal to X P R) A Ruler laid from P to L (where the *Great Circle* Q P R cuts the *Equinoctial* Circle) will cut the Circle in *h*, so the distance S *h* 61 deg. 17 min. is the *Plain's Difference* of *Longitude*.

5. For the *Hour-Distances*, they are found by laying a Ruler from Q to the several intersections of the *Hour-Circles* of the *Projection* with the *Reclining Plain*, and where the Ruler cuts the *Primitive Circle*, make marks or * * *, through which *Points* or marks, if you draw Lines from the Centre Z, they shall be the true *Hour-Lines* for this *Declining Reclining Plain*.

II. *By* Trigonometrical *Calculation*.

The first thing to be done is to find the *Requisites*, and they will be all found in the three Spherical Triangles Z F O, O P R, and B N X.

1. For A O, In the Triangle Z F O, there is given (1) Z F the *Plain's Reclination*. (2) O Z F the *Plain's* Declination, and (3) The *Right Angle* at F. To find O A, or its Complement O F,

As the Radius 90 deg.	10.00000
To the Sine of Z F the Reclination 54 deg.	9.90795
So is the Tangent of O Z F, the Declination, 60 deg.	10.23856
To the Tangent of F O 54 deg. 29 min.	10.14651

Whose Complement is A O 35 deg. 31 min. for the *Substile's Distance* from the *Meridian*.

2. For R O, In the Triangle O P R there is not yet enough given; therefore, First find the side Z O in the Triangle O Z F.

As the Sine of the Plain's Declination O Z F 60 deg.	9.93753
To the Radius 90 deg.	10.00000
So is Sine of Dist. of Mer. and Hor. O F 54 d. 29 m.	9.91059
To the Sine of Z O 70 deg. 2 min.	9.97306.

Unto this 70 deg. 2 min. add Z P 38 deg. 28 min. the sum is 108 deg. 30 min.

Then

Then by the two Proportional Triangles O Z F and O P R.

As the Sine of O Z 70 d. 1 m. *Hypotenuse*	in the Tria.	9.97307
To the Sine of Z F 54 d. *Perpendicular*	O F Z	
So Co-sine of P O to 180-71 d. 30 m. *Hyp.*	in the Tri.	9.90796
To the Sine of P R 54 d. 43 m. *Perpendicular*	O P R	9.97696
		19.88492
		9.91185

Which is the *Height* of the *Pole* or *Stile* above the *Plain.*

3. For R O, or its Complement R X, Continue the sides O P and O R of the *Triangle* O P R, and you shall constitute another *Triangle* N X B, and then the Proportion for finding R O will be;

As the Tangent of Z F the Reclination 54 deg.	10.13874
To Sine of F O, Co-dist. of Mer. and Hor. 54 d. 29 m.	9.91059
So is the Tangent of P R, the Stile's Height 54 d. 43 m.	10.15021
To the Sine of R X 56 deg. 42 min.	20.06080
	9.92207

Which 56 deg. 42 min. is the *Substile's Distance* from the *North* part of the *Meridian*, whose Complement to 180 deg. is 123 d. 19 m. its *distance* from the *South* part thereof.

4. For the Angle O P R, or its Complement R P X;

As the Sine of P R, Stile's Height 54 deg. 43 min.	9.91184
To Tan. of R X, Substile's dist. from Mer. 56 d. 42 m.	10.13851
So is the sine of P R X, Radius 90 deg.	10.00000
To the Tangent of R P X 61 deg. 48 min.	10.27067

R P X being 61 deg. 48 min. is the *Angle* counted from the *North*, therefore the *Angle* O P R, the Complement to 180 deg. is 118 deg. 13 min. the *Plain's Difference* of *Longitude* reckoned from the *South*.

These things prepared, I proceed to make the *Table* for the *Hour-Distances* from the *Substile*, wherein considering that the Angle P, the *Plain's Difference* of *Longitude* is 118 deg. 12 min. reckoned from the South, whereof 90 deg. is answerable to 6 Hours, and 105 to 7 Hours, and there is yet remaining 13 deg. 13 min. it is evident, for the *Substile* must be drawn between the Seventh and Eighth Hour from the *South* part of the *Meridian*, or between the Fourth or Fifth Hour reckoned from the *North* part.

Wherefore set the *Hours* down as in the *Table*, and between the Hours of 4 or 8, and 5 or 7, write *Substile*, setting the remainder 31 deg. 13 min. under *Substile*, and the Complement thereof to 15 deg. viz. 1 deg. 47 min. over *Substile*, and by the continual addition of 15 deg. to both these numbers, you shall produce the *Equinoctial Distances*

Latitude	51	32
Declination	60	00
Reclination	54	00
Dist. Mer. & Hor.	35	31
Stile's height	54	43
Deflection	123	19
	56	41
Differ. of Long.	118	13
	61	74

Hours from the Substile.		Equinoctial Distances. D.	M.	Hour-distances from the Substile. D.	M.
11	1	76	47	73	57
12		61	47	56	41
1	11	46	47	40	59
2	10	32	47	26	50
3	9	16	47	13	50
4	8	1	47	1	27
The		Sub-		stile.	
5	7	13	13	10	51
6	6	28	13	23	39
7	5	43	13	37	29
8	4	58	13	52	48
9	3	73	13	69	43
10	2	88	13	87	49

ſtances as in the *Second Column* of the *Table*: And thoſe by the general *Canon*, will help you to the true *Hour-Diſtances* upon your *Plain.* For,

As Radius 90 deg. 10.00000

To the Sine of 54 d. 43 m. the Stile's Height — 9.91185

So is the Tang. of 28 d. 13 m. the Equi. Diſt. for 6 a Clock — 9.72963

To the Tang. of 23 d. 39 m. — 9.64148

Which is the true Diſtance of the *Six* a Clock Hour from the *Subſtile* of the *Dial.*

And thus continuing this *Proportion* through all the *Equinoctial Diſtances*, you will in the end have ſuch numbers to every *Hour* as the third *Column* of the *Table* ſheweth, which are the true *Hour-Diſtances*, counted from the *Subſtile* upon your Plain.

The *Meridian*, *Horizon*, *Subſtile* and *Hour-Diſtances* may be tranſferred from this *Table* to the *Dial-Plain* at pleaſure, by help of a large *Chord* and *Beam-Compaſſes.*

CHAP. XIX.

Of Dial Plains, *and how one* Plain *may be deduced from another, a* North *from a* South, *an* Eaſt *from a* Weſt, *a* North Decliner *from a* South Decliner; *and all* Inclining Plains *from* Recliners *oppoſite to them.*

As there were Six Varieties of Direct Reclining Plains, and as many of Recliners which do alſo decline; ſo there are as many of both ſorts which do Incline, and Incline and Decline alſo; of all which it may be expected I ſhould give particular Examples, as of North and South Direct Recliners, and North and South Recliners which do alſo decline. —— But for as much as a Direct North Dial may be deduced from a Direct South Dial, and a Direct Weſt Dial from a Direct Eaſt Dial; as by *Chap.* VIII. *Fig.* II and III, and *Chap.*

Chap. IX. *Fig.* IV, and V. of this Tractate do plainly demonstrate: So from a South Declining Plain, may a North Declining Plain also; be deduced; and this is also demonstrated in *Chap.* XII, *Figure* VI and VII; at the end of which 12th *Chapter* I use these words, [" From this South " Plain declining West, a South Dial is also Declining East 30 deg. " turning of the East side to the West side, and the contrary; and by " changing the names of the Hours, by calling 11 One, 10 Two, " 9 Three, *&c.* Also 1 Eleven, 2 Ten, 3 Nine, *&c.* The Fore- " noon Hours in the West Declining Dial being the Afternoon " Hours in the East Declining Dial, and the contrary] —— Now because these kind of Dials, are of all other most common in use, and to make them the more conspicuous to every Mans Eye, I have in this Chapter, *Figure* XXIII, made Four Dials together, all of them deduced from one Dial, namely, A South Declining East and West 30 deg. and a North Declining East and West as much, only placing the numbers of the Hours and Stile respectively upon each Plain. In which XXIII *Figure*, you may plainly see, that there is no difference at all between the South declining East, and the South declining West, but that the Forenoon Hours on the Left Hand of the Meridian in the East Dial, are become the Afternoon Hours, and on the Right Hand of the Meridian in the West Dial; and the contrary. The Stiles of the Dials also, must of necessity change their places, for the Stile which in the East declining Dial stands between the Hour Lines of 9 and 10 in the Fore-noon, stands between the Hour Lines of 2 and 3 in the Afternoon —— And in this XXIII *Figure* you may also observe that each North Dial is formed out of its correspondent South, by only drawing of the Hour Lines, Stile and Substile, of the South Dial through the Center. And so is the North declining West Dial 30 deg. deduced from the South declining East Dial 30 deg. And the North declining East Dial, out of the South declining West —— And from hence it followeth of necessity, that the South side of the Plain declining West, the North side thereof declineth as much towards the East, and the contrary. And this also holdeth in all other Dials, as shall be made appear. For, *Figure* XXIII.

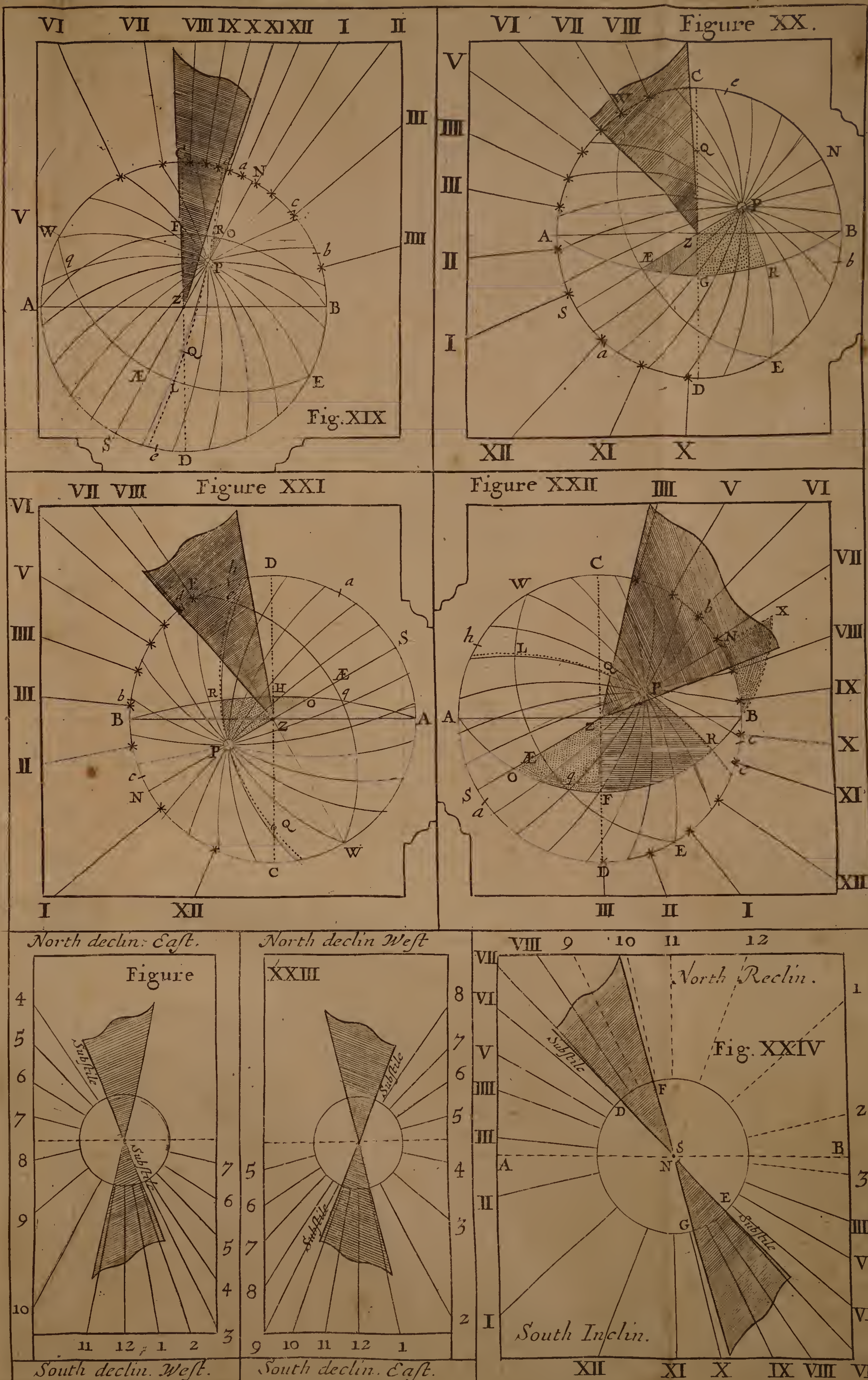
In the 14th Chapter of this Tractate, *Figure* IX, you have an East Incliner, deduced from a West Incliner —— In Chapter XV Section 2, *Figure* XI, You have a North Inclining Dial 25 deg. deduced from a South Dial Reclining as much, namely, 25 deg. —— Also *Chap.* XVI, *Sect.* 2 and 3, *Fig.* XIV and XV; by the former Artifice may two South Incliners be deduced from the two North Recliners, although Lines are not drawn (because the Hour Lines, proper for the Recliners, do occupy both parts of the Plain, above and under the Hours of Six) yet the reason of effecting what is here intended, may be easily conceived.

Again, In this Chapter *Figure* XXIV, You have a North Reclining Plain declining Westward 60 deg. And if from thence you would make a South Inclining Plain declining 30 deg. the very sight of the *Figure* is enough to inform you. But least any doubt should arise, Let A 3, 4, 5, 6, 7, 8, be the Hours of the Recliner, and D S the Stile thereof, which drawn through the Center to E, take the distances of each Hour from D, and set them from E, the Hours under D above E, and the contrary; or else draw them all through the Center, Stile *Figure* XXIV.

and

and all, to the oppoſite ſide of the Plain, as you did the Subſtile, and ſet the ſame Numbers to the Hour-Lines continued that were in the Recliner, ſo have you made the Inclining Dial to the ſame Plain, which, notwithſtanding, muſt be prickt through the Paper, and taken on the other ſide thereof.—And here you may obſerve how the two Dials are divided one from the other. The Center of the Recliner downwards, and the Axis S F, with the Hours pointing upwards to the North Pole, and the Axis N G, with the Hours thereof, pointing downwards towards the South Pole, and the whole Diurnal Arch of 16 Hours ſupplied by the two Plains; the Incliner receiving the Sun at Four in the Morning, and the Recliner continuing the ſame till Eight at Night, and when the Sun forſakes the Inclining Face, it illuminates the Reclining or upper Face—And for further Satisfaction and Explanation of what in this Chapter hath been delivered, Let the upper Face, or the Recliner A S F, be turned about till it become the neather part, or the Incliner B N G, and after this converſion, let the Hour-Lines on the right hand of the Subſtile near D in the Recliner, be made the Hours on the left hand of the Subſtile, near E, in the Incliner; and the contrary, which may eaſily be done, by ſuppoſing A F S to be carried about the Center S Horizontally (with the reſt of the Dial) till F become placed in G, and A in B, and then you ſhall ſee the Incliner is the very ſame as the Recliner was, and ſo by conſequence the one formed out of the other.

A



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A SUPPLEMENT TO THE *FIRST TRACTATE:*

SHEWING

A General and Easie Way to Project Hour-Lines *upon all Sorts of* Plains, *according to the* Rules *of* Stereographick *or Circular* Projection *of the Sphere* in Plano.

HAving in the foregoing *Tractate* shewed how to describe *Hour-Lines* upon all sorts of *Plains*, how much and in what Latitude soever situate, by *Projecting* of the *Sphere* suitable to the *Latitude* of the *Place* where any such *Dial* is to be made; and discovered thereupon the *Spherical Triangles*, whereby the *Requisites* belonging to every *Plain* may be *Calculated* by the *Canons* of Artificial *Sines* and *Tangents*, (which of all others, is the most *exact* and *absolute* way of *Performance*) it may seem unnecessary to say any thing more concerning that matter in this place.

But, forasmuch, as it is there required first to *Project* the *Sphere* upon the *Horizon* of the *Place*, and describe the *Meridians* and *Hour-Circles* thereupon; and then the *Great Circle* which is to represent the *Plain:* I shall here (to express the more variety in *Projection*, and) for the satisfaction of the more inquisitive *Reader* in this matter; briefly discover unto him, how to describe *Hour-Lines* upon all sorts of *Plains* (according to the Rules of *Stereographick Projection*) without the drawing of the *Meridians* or *Hour-Circles* upon the *Projection:* but by making the *Fundamental* or *Primitive Circle* to represent the *Dial-Plain* it self, what ever it be; whether *Horizontal*, *Vertical*, *Direct*, *Declining*, *Reclining* or both; giving *Examples* in all the *Varieties* of *Plains* mentioned in the foregoing *Tractate*.

And to pass by the Eight first *Chapters* of the said *Tractate* as consisting of such things as are common to all sorts of *Projections* of the *Sphere*, and to all kinds of *Dialling*, whether, *Arithmetical*, *Geometrical* or *Instrumental*; I shall begin with the *Example* in CHAP. IX. which is,

SECT.

SECT. I.

How to draw an Horizontal *Dial in any Latitude: viz.* London, *whose Latitude is* 51 d. 32 m.

Figure I. UPon Q, as a Center, describe a Circle to represent your *Horizontal Dial Plain:* And cross it with the Diameters N S, for the *Meridian* and *Hour Line* of 12, and W E for the *Hour Line* of 6, crossing each other in Q, the *Center* of the *Dial Plain.*

Then, the *Latitude* being 51 d. 32 m. take 51 d. 32 m. out of your *Scale* of *Chords*, and set them from S to *a*, and from W to *b*, a Ruler laid from W to *a*, will cut the Meridian in P, the *Pole* of the *World* [or, *The half Tangent of* 38 d. 28 m. [*the Complement of the Latitude being set from* Q, *will give the same Point* P, *for the Pole of the World*] Also, a Ruler laid from E to *b*, will cut the *Meridian* N S in Æ, the point of the intersection of the *Meridian* and *Equinoctial* [or, *The half Tangent of the Latitude* 51*d.* 32*m. set from* Q, *will give the same Point*] And now you have three Points, viz. W Æ E, through which you may draw the *Equinoctial Circle* W Æ E, whose *Center* is at C, and the Semidiameter thereof Æ C, equal to the *Secant* of 38 d. 28 m. the *Complement* of the *Latitude.*

This done, Divide the Semicircle W N E, into 12 Equal Parts, at the Points ⊙ ⊙ ⊙, *&c.* Then lay a Ruler to Q, and every one of those Points ⊙ ⊙ ⊙, and the Ruler will cross the *Equinoctial* Circle W Æ E, in the points *x x x*, *&c.* dividing it into 12 unequal parts. Again, Lay a Ruler to P, the *Pole* of the *World*, and to every of the Points *x x x*, *&c.* and it will cut the Circle W N E (representing the *Horizontal Plain*) in the Points 1, 2, 3, *&c.* on one side of N, and in 11, 10, 9, *&c.* the other side.

Lastly, From the Center Q, and through those Points 1, 2, 3 : 9, 10, 11, *&c.* draw Right Lines, and they shall be the true *Hour Lines* proper for an *Horizontal Dial* for the *Latitude* of 51d. 32m.

For the *Stiles height* (which is always equal to the *Latitude* of the Place) and for the placing of it, see the 9th *Chapter.*

The Xth *Chapter* is, *To make an Erect Direct South or North Dial:* ——— Now a *South* or *North Dial* in any *Latitude*, is no other than an *Horizontal Dial* in that *Latitude* which is equal to the Complement of the other *Latitude*, so an *Erect Direct South Dial* for the *Latitude* of *London* 51 deg. 32m. is no other then an *Horizontal Dial* made for the *Latitude* of 38 deg. 28 min. And may be made by the Artifice deliver'd in this *Section.*

The XI*th Chapter* is, *To describe Hour Lines upon an Erect Direct East or West Plain* ——— *East* and *West Dials* in all *Latitudes* are the same, and may be made by the Rules delivered in the 11th *Chapter* with this *Caution* only: That the *Equinoctial Line* G H in those *Figures*, must make an *Angle* with the *Horizontal Line* of the Plain D C, equal to the *Complement* of the *Latitude* of the *Place* for which the *Dial* is to be made.

SECT.

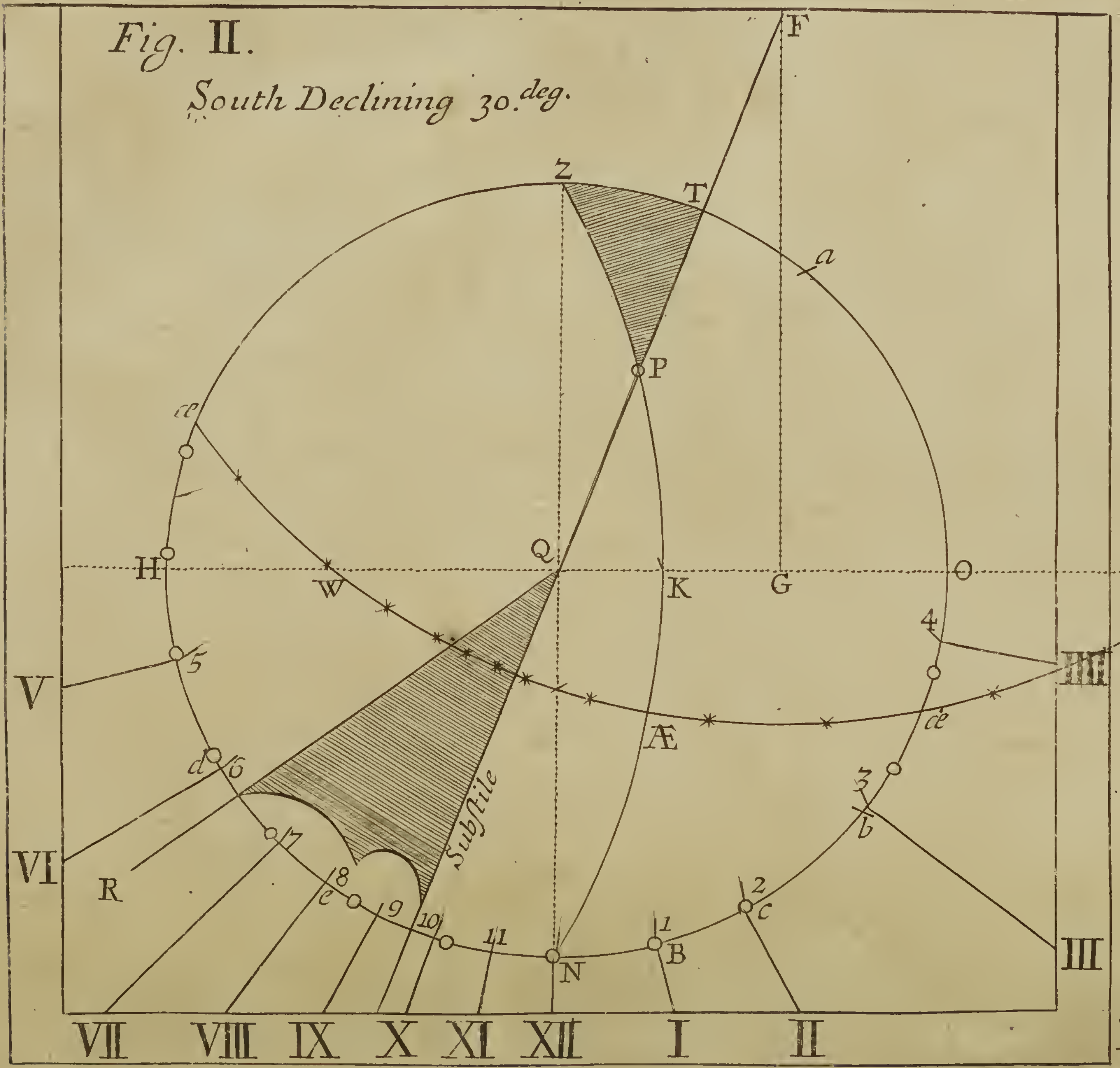
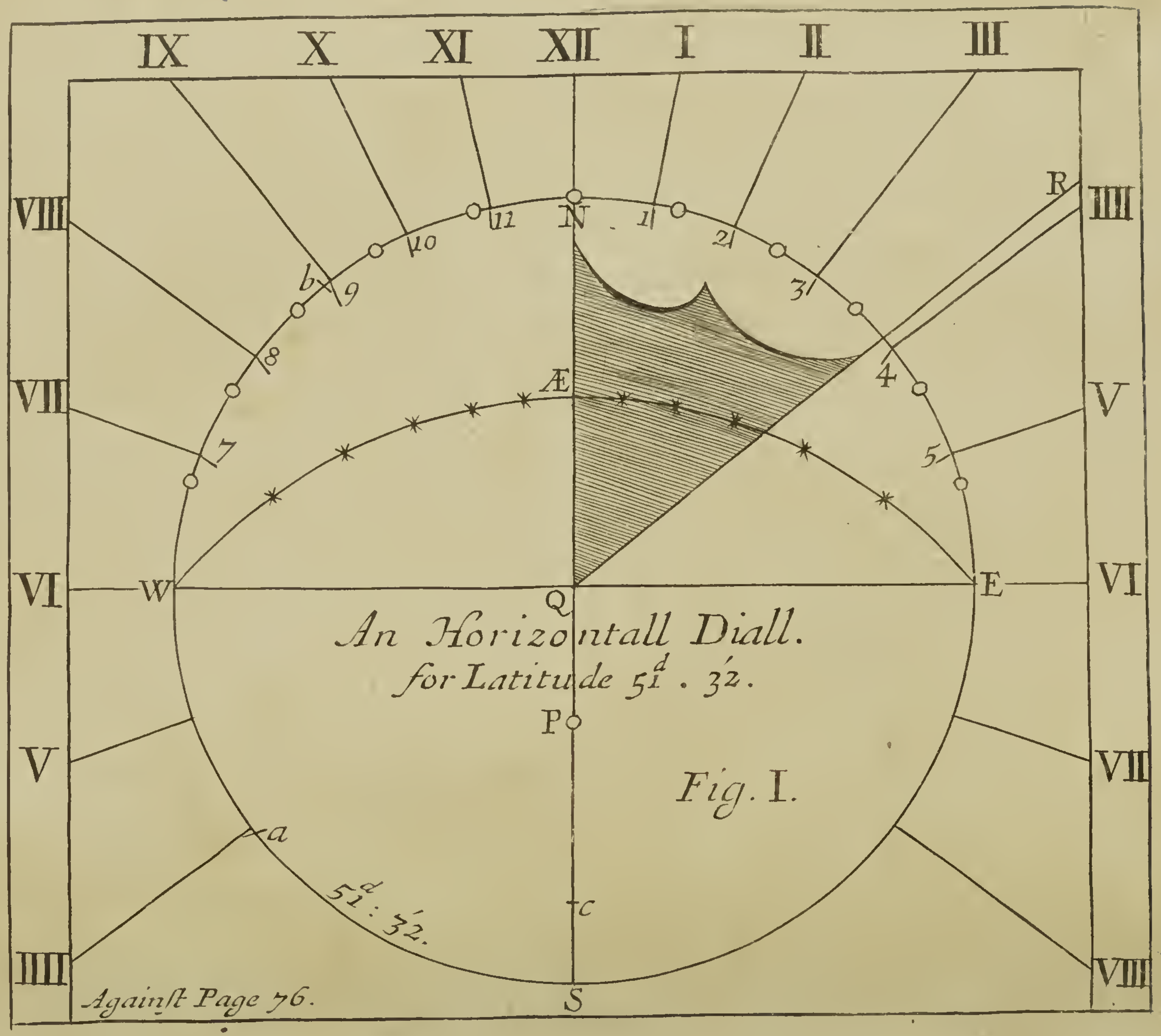


Fig. II.

South Declining 30.deg.

Againſt Page 77.


IX
X
XI
XII
I
II
III
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VII
VIII
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11
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9
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7
1
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4
5
R
Æ
W
E
Q
P
c
S
a
51d : 32'.
An Horizontall Diall.
for Latitude 51d . 32'.
Fig. I.
Against Page 76.

SECT. II.

How to deſcribe Hour Lines, *upon an Erect* South *or* North Plain, Declining *East or West.*

IN the Latitude of *London*, which is 51 deg. 32 min. Let it be required to make a *South Erect Dial, Declining East* or *West* 30 degrees.

This is the Work of *CHAP.* XII. And ſuch a Dial may be made by this way of *Projection*, by theſe *Rules* following.

First, Upon Q, as a Centre, Deſcribe a Circle to repreſent your *Upright Declining Plain*, G; croſs it with the two Diameters Z Q *N* for the *Vertical*; and H Q O for the *Horizontal Line* of the *Plain.* *Figure* II.

Secondly, Out of your Scale of *Chords* take 30 deg. the *Plains Declination* and ſet them from N to *c*, if the *Declination* be *Eaſtward* (as here it is) or from N to *e*, if the *Declination* had been *Weſtward*; Then lay a Ruler from Z to *c*, and it will cut the *Horizontal Line* of the Plain in K, ſo have you three Points Z, K and N, by which to draw the Arch Z K N, for the *Meridian of the Place* [Or, *The half Tangent of* 30 *deg. ſet from* Q *will give the ſame* K: *And the half Tangent of* 60 *deg, the Complement thereof, ſet from* Q, *will give you the Point* W, *for the West Point of the Horizon and Pole of the Meridian.*] And the Secant of 60d. ſet from K, upon the Line K H, extended, will give the Centre, whereon to deſcribe the *Meridian Circle.*

Thirdly, Out of your Scale of *Chords*, take 51 deg. 32m. the *Latitude* of the Place, and ſet them from O to *a*, and from N to *b*; A Ruler laid from W to *a*, will croſs the *Meridian* in P, the *Pole* of the *World*: and laid from W to *b*, it will croſs the *Meridian* in Æ, the Point where the *Equinoctial* Circle will cut the *Meridian*: And thus have you two Points W and Æ, through which you may (by the 12th. *Prop.* at the beginning of this Book) deſcribe the *Equinoctial Circle* W Æ E which will (being continued without the Circle) croſs the *Horizontal Line* of the Plain H O (that being continued) in E, which is the *East* Point of the *Horizon.*

Fourthly, Through P, the *Pole* of the *World*, and Q, the Pole of the Plain, draw P Q for the Axis of the *World*, and *Subſtilar line* of your *Dial*, in which Line the Centre of the *Equinoctial* will be.

Fifthly, Divide the ſpace between W and E, into two equal parts in G, and on G, erect a Perpendicular, which will cut the *Axis* of the *World* Q P, extended, in F, which is the *Centre* of the *Equinoctial Circle*: (if you have truly wrought.)

Sixthly, From P the Pole of the World, lay a Ruler to Æ, the interſection of the *Meridian* with the *Equinoctial*, and it will cut the Circle in B; At this point B, begin to divide the Semicircle H N O, into 12 equal parts, at the points ⊙ ⊙ ⊙ *&c.*

Seventhly, From Q (the *Pole* of the *Plain*) lay a Ruler to every of the *Points* ⊙ ⊙ ⊙, *&c.* and it will croſs the *Equinoctial Circle æ Æ æ*, in the Points x x x, *&c.*

Eighthly, lay a Ruler to P, (the *Pole* of the *World*) and every of the Points * * *, *&c.* and it will cut the *Primitive Circle* repreſenting the *Plain* in the Points N, 9, 10, 11, N, 1, 2, 3, *&c*, Through which

Points; Lines drawn from the Centre Q, shall be the true *Hour Lines* of an *Erect South Plain*, *Declining Eastward* 30 *deg.* in the *Latitude* of 51 deg. 32 min.

Concerning the *Requisites* belonging to any *Upright Declining Plain* they are all of them represented to the eye, in the *Spherical Triangle* Z T P, Right angled at T, In which

The Side	Z T, is the Distance of the *Substile* from the *Meridian*	21	49
	Z P, the Complement of the *Latitude* of the Place	38	28
	T P, the height of the *Pole* above the *Plain*	32	36
The Angle	P Z T, the Complement of the *Plains Declination*	60	00
	Z P T, the *Plains Difference of Longitude*	36	25
	Z T P, is a Right Angle.	90	00

And all these may be found by *Trigonometrical Calculation*, as is shewed at large in the foresaid 12th. *Chapter*, As also, the manner how to place the *Stile*, and from one *Declining Dial* to make *Four* of the same *Declination*, &c.

The XIIIth. *Chapter* Is, *To draw Hour Lines, upon a South or North Plain, which Declines many Degrees toward the East or West.*

For the making of such *Dials*, no better ways can be prescribed than are there delivered in the said *Chapter* and so I say no more of them in this place.

The XIVth *Chapter* Is, *How to describe Hour Lines upon Direct East or West Reclining Plains.*

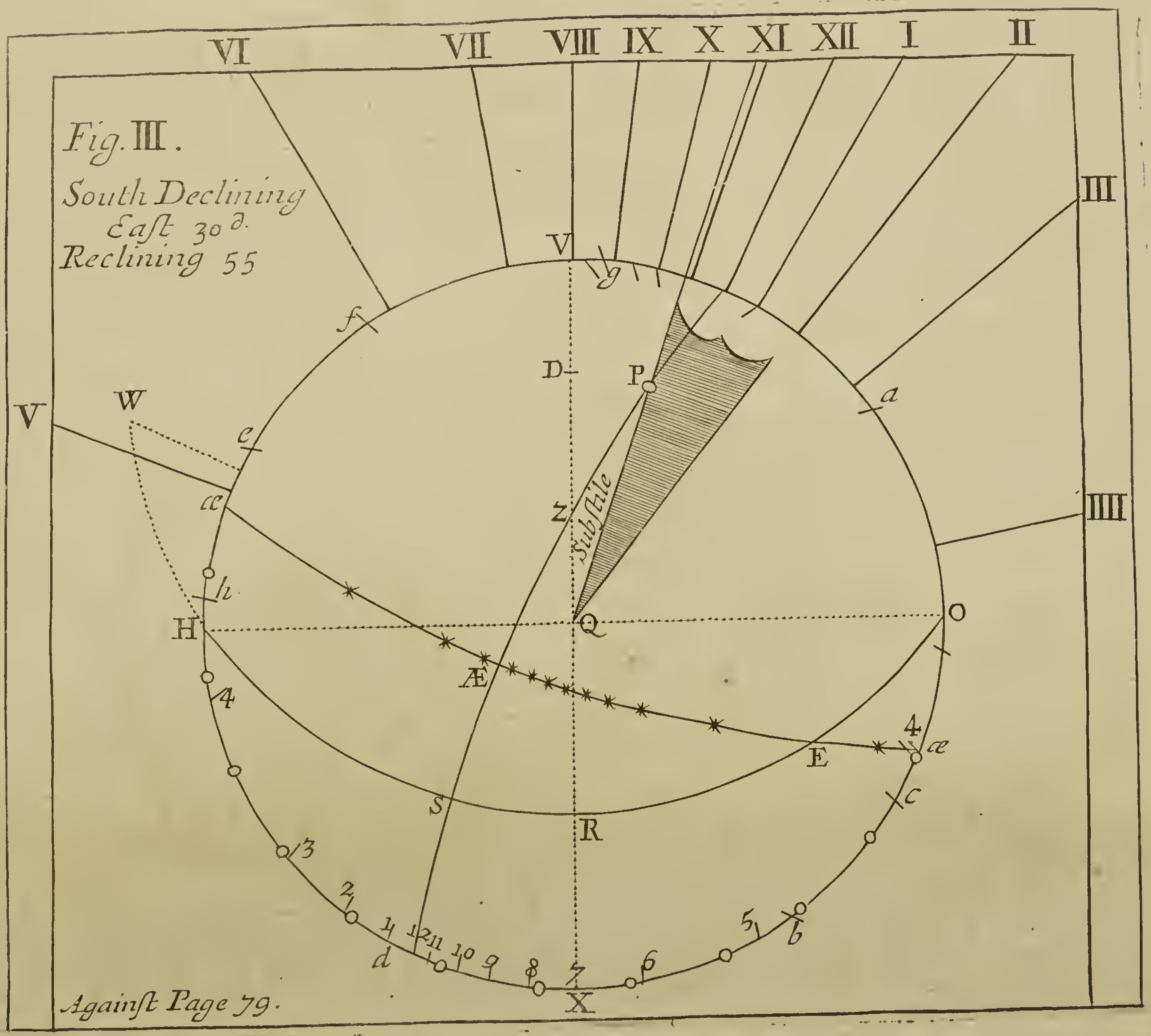
Hour Lines may be described upon such Plains by the Precepts delivered in this Section; if first you reduce them to a *New Latitude*, and a *New Declination*, wherein they may become *Upright Declining Plains* in that *New Latitude*: Which is very easie to be done ——— For a *Direct East* or *West Dial Reclining* 35 deg. in the *Latitude* of 51 deg. 32 min. (and such a *Plain* is the *Example* in *Chap.* 14) may be Reduced to a *New Latitude*, and *New Declination.* For, The *New Latitude* will be the *Complement* of the *Old Latitude*: And the *New Declination* the *Complement* of the *Reclination:* So, the above-mentioned *Plain*, will be a *South Plain Declining* 55 deg. in the *Latitude* of 38 deg. 28 m. And a *Dial* made to such *Latitude* and *Declination* shall be an *East* or *West Dial Reclining* 35 deg. in the *Latitude* of 51 deg. 32 m. But, whereas in the *Upright Declining Plain* the *Hour Line* of 12 is, always, *Perpendicular*; so the *Line* of 12 in the *Reclining Plain*, must be, always, *Parallel* to the *Horizon*. For finding the *Requisites* belonging to these *Plains*; &c. See the *Rules* and *Cautions* in *Chap.* 14.

The XVth. *Chapter* sheweth, *How to draw Hour Lines upon Direct South Dial Plains Reclining from the Zenith.*

Of these there are *Three Varieties*, and all of them are Reducible to *New Latitudes* where they will be *Horizontal Plains*; for, the height of the *Stile* or *Pole* above any *South Direct Reclining Plain*, is the *New Latitude* wherein that *Reclining Plain* would be an *Horizontal Plain*: Now the *three Varieties* of the Plains there mentioned have

In the	First	Variety	00 d	00 m	For the height of the *Pole* above the Plain.
	Second		13	28	
	Third		31	32	

And so, *Horizontal Dials* for those *Latitudes*, being made according to the Directions in the *First Section* hereof will be such *Reclining Dials* as are taken for *Examples* of the *Three Varieties* in that *Chapter*, where how



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how to find the *Height of the Pole* above any South *Reclining Plain* is plainly taught, as also how to place the *Stile* and *Dial*, *&c.*

The XVIth *Chapter* Sheweth; *How to draw Hour Lines upon Direct North Dial Plains Reclining from the Zenith.*

Of these also there are *Three Varieties*; Reducible also to *New Latitudes* wherein they will become *Horizontal Plains*: And how to find these *New Latitudes*, which is the height of the *Pole* or *Stile* above the *Plains*, is there shewed and

In the	First	Variety	90d	00m	Is the height of the *Pole* or *Stile* above the *Plain.*
	Second		63	28	
	Third		71	32	

And so *Horizontal Dials* made for those *Latitudes*, shall be such *Reclining Plains* as are the *Examples* in the abovesaid 15th *Chapter.*

SECT. III.

How to describe *Hour Lines* upon such *Plains*, as do both *Decline* from the *North* or *South*, and *Recline* from the *Zenith* of the Place.

OF these Plains there are two kinds principally, *viz.* such whose *Faces* behold the *South*, and such whose *Faces* behold the *North*: and in either of these there are *Three Varieties*, of which you may see several *Examples* in the 17th and 18th *Chapters* of the preceding *Tractate.* It shall suffice therefore (in this *Supplement*) to give only *two Examples*, One a *South* Plain *Declining Eastward* 30 deg. and *Reclining* from the *Zenith* 55 degrees. And another of a *North* Plain, Declining *Westward* 60 deg. and *Reclining* from the *Zenith* 54 deg. both in the *Latitude* of 51 deg. 32 m. *Examples* of both which you shall find in the *three Varieties* of the two above-mentioned *Chapters.*

The third Variety in the XVIIth *Chapter* Is *How to describe Hour Lines upon a South Plain, Declining Eastward* 30 *deg. and Reclining from the Zenith* 55 *deg. in the Latitude of* 51 *deg.* 32 *m.* Now, to make such a Dial by this Artifice, you must,

First, Upon Q, as a Centre, describe a Circle to represent your *Declining, Reclining Plain*; and cross it at Right angles in Q, with the Diameters H O, for the *Horizontal*, and V X for the *Vertical Lines* of the Plain. Figure III.

Secondly, Take 55 deg. the *Reclination*, and set them from V to *a*, and from O to *b*, a Ruler laid from H to *a*, will give the Point Z, for the *Zenith* of the Place, and from H to *b*, it will give the point R, for the intersection of the *Vertical Line* of the *Plain*, with the *Horizon* of the Place: [Or, *The half Tangent of* 35, *the Complement of the Reclination set from* Q, *will give the point* Z, *and the half Tangent of* 55, *the Reclination will give the point* R].

Thirdly, Through the three Points H R O, you may draw the *Horizon* of the Place, whose Centre will be at D, the Semidiameter whereof D R is equal to the *Secant* of 35 deg. the complement of the Plains *Reclination.*

Fourthly, Take 30 deg. the Plains *Declination*, out of your Scale of *Chords*,

Chords, and set them from O to *c*, from X to *d*, and H to *e*, and a Ruler laid from Z to *c*, will give the point E, and laid from Z to *d*, will give the point S, and laid from Z to *e*, will give the Point W, all in the *Horizontal Circle*, for the true *East*, *South*, and *West* Points thereof.

Fifthly, Through the Points Z, the Zenith, and S, the South point of the *Horizon*, you may (by the 12th *Problem* at the beginning of this Book) Draw the *Meridian* of the Place S Z P,

Sixthly, Lay a Ruler to the Points E and Z, and it will cut the Primitive Circle in *f*, from *f*, set 38 de. 28 m. of your Scale of *Chords*, and they will reach from *f* to *g*, and a Ruler laid from E to *g*, will cross the *Meridian Circle* in P, the *Pole* of the *World*: and 90 de. of your *Chords*, set from *g*, will reach to *h*, and a Ruler laid from E to *h*, will cross the *Meridian* in Æ, and so you have three Points W, Æ and E, through which to draw the *Equinoctial* Circle æ Æ æ.

Seventhly, Through Q the *Pole* of the *Plain*, and P the *Pole* of the *World*; draw the right line Q P for the *Axis* of the *World*, and the *Substilar* line of your Dial: it must be drawn upwards towards the *North*; because the *North Pole* is elevated above this Plain, as is manifest by the *Scheme*.

Eighthly, Lay a Ruler upon P, the Pole of the World, and Æ, where the *Meridian* and *Equinoctial* intersect, and it will cut the *Primitive Circle* in B.

Ninthly, At the Point B, begin to divide the *Primitive Circle* into 24*l*, (or the half of it æ B æ into 12) equal parts, at the Points ⊙ ⊙ ⊙, *&c.*

Tenthly, Lay a Ruler to Q, and every of those Points, and it will cross the *Equinoctial* Circle æ Æ æ, in the Points x x x *&c.* And a Ruler laid from P, the *Pole* of the World, to every of these Points; x x x, *&c.* will cut the *Primitive Circle* representing the *Dial Plain*, in the Points 5, 6, 7, 8, 9, 10, 11, 12, 1, 2, 3, 4, from which Points, Right Lines being drawn through the Centre Q, (upwards, because the *North Pole* is elevated above the *Plain*) they shall be the *Hour Lines* belonging to such a *Declining Reclining Dial* as was required to be drawn.

As concerning the *Requisites* belonging to this *Declining Reclining Dial*, they are all visible in the *Projection*, and three of them in the Triangle L P C. For,

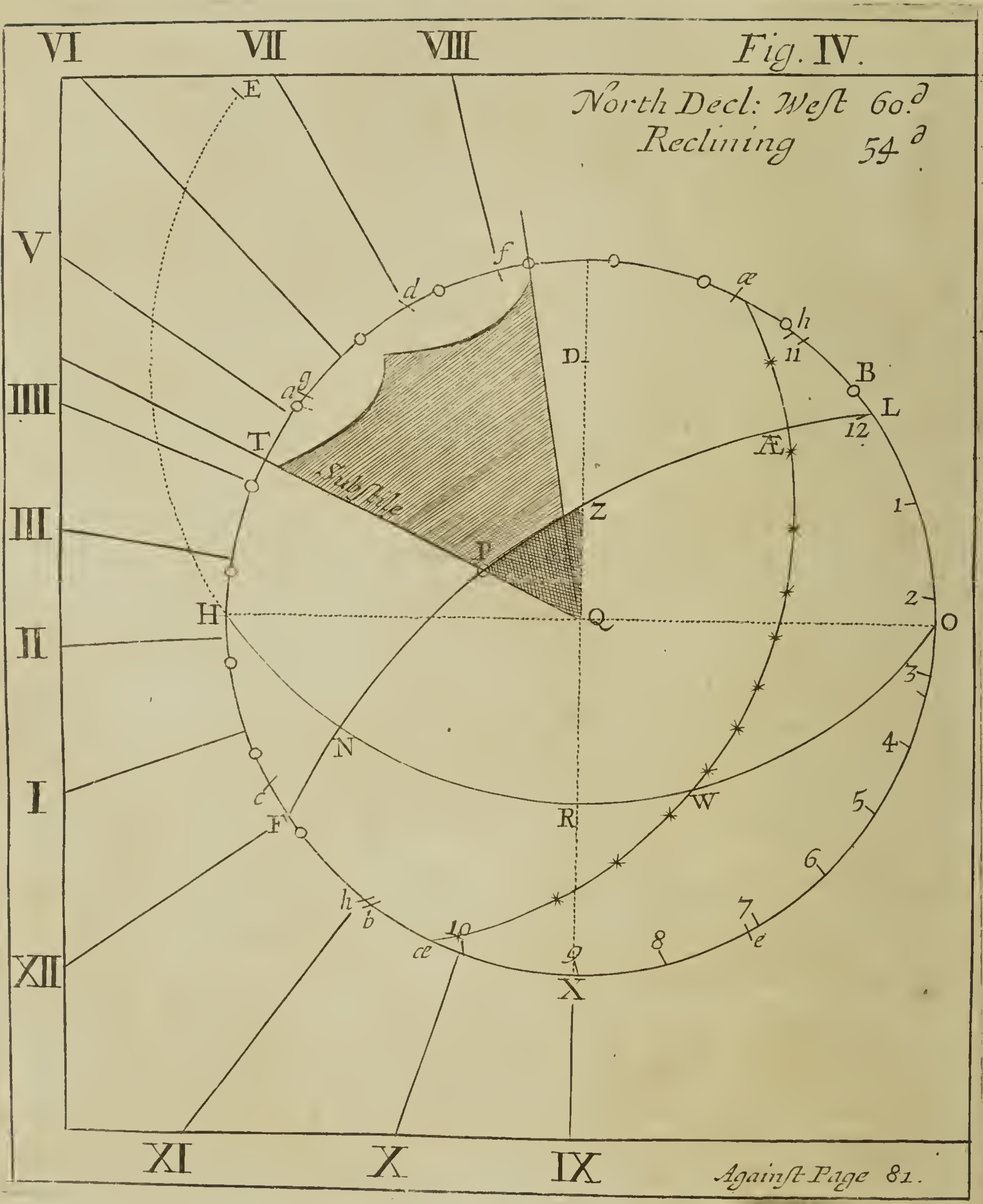
	de	m
The height of the *Pole* above the *Plain* is C P,	19	25
The Distance of the *Substile* and *Meridian* C L,	06	02
The Plains *Difference* of *Longitude* L P C,	17	38
The Distance of the *Meridian* and *Horizon*, is the *Arch* O C	64	41

As by the Trig. Calculation doth appear.

The Third Variety in the XVIIIth. Chapter Is how to describe *Hour Lines, upon a North Plain, Declining West* 60 deg. and *Reclining from the Zenith* 54 deg. in the *Latitude* of 51 deg. 32 m. and to make such a Dial according to this way of Projection: you must,

Figure IV. First, Upon the Centre Q, with 60 deg. of your Scale of *Chords*; describe a Circle representing the Dial Plain; and cross it with the two *Diameters* V X for the Vertical, and HO, for the *Horizontal Lines* of your Plain.

Secondly, Take 54 deg, the Plains Reclination, out of your Scale of *Chords*,



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Chords, and ſet them from U to *a*, and from H to *b*, a Ruler laid from H to *a*, *b* will cut the Vertical Line of the Plain U X, in the Points Z, for the Zenith of the Place; and in R, for the Point of Interſection of the Horizon of the Place, with the Vertical Line of the Plain; and now you have three points, thro' which to draw the Horizontal Circle H R O, whoſe Center will be at D.

Thirdly, Take 60 degr. the Plain's Declination, and ſet them from O to *e*, from H to *d*, and from X to *f*, a Ruler laid from Z to *e*, will give the point W; and from Z to *c*, will give the Point N; and laid from Z to *d*, will give the point E; all in the Horizontal Circle, for the true *East*, *North* and *West* points thereof.

Fourthly, Thro' the Zenith Z, and *N*, the North-point of the Horizon, you may (by *Probl.* 12.) draw the Meridian of the Place N Z.

Fifthly, Lay a Ruler from W to Z, and it will cut the Primitive Circle in *f*; from *f* ſet 38 degr. 28 min. the Complement of the Latitude, and they will reach from *f* to *g*; and a Ruler laid from W to *g*, will croſs the Meridian-Circle in P, the Pole of the World: And 90 degr. being ſet from *g* to *h*, a Ruler laid from W to *h*, will cut the Meridian-Circle in Æ; and ſo you have three Points, N, W, and Æ, thro' which to draw the Æquinoctial-Circle æ Æ æ.

Sixthly, Thro' P, the *Pole* of the World, and Q, the *Pole* of the Plain, draw the Right Line Q P L, for the *Axis* of the World, and Subſtilar Line of your Dial.

Seventhly, Lay a Ruler to P, the *Pole* of the World, and Æ, where the Meridian and Æquinoctial interſect, and it will cut the Primitive Circle in B: At this Point B, begin to divide the Circle repreſenting your Dial-plain, into 24 (or the half thereof into 12) equal parts, in the points ⊙ ⊙ ⊙, *&c.*

Eighthly, Lay a Ruler to Q, and every of thoſe points, it will croſs the Æquinoctial Circle æ Æ æ, in the points * * *, *&c.* and a Ruler laid to P, and every of thoſe points * * *. will cut the Primitive Circle in the points, 9, 10, 11, 12, 1, 2, 3, 4, 5, 6, 7, 8. From which points, Right Lines being drawn from the Center Q, ſhall be the true Hour Lines proper for your Declining Reclining Plain.

The Requiſites belonging to the Plain, are viſible in this *Projection*, as in the other. For,

		degr.	*min.*
The Diſtance of the *Meridian* and *Horizon*, is	O L	35	31
The Height of the *Pole* above the *Plain*, is	P T	53	43
The Diſtance of the *Subſtile* and *Meridian*, is	T F	56	41
The *Plain's* Difference of Longitude, is	Z P Q	61	47

A SYNOPSIS, OR ABSTRACT, OF

What hath been delivered more at large, in the fore-going Chapters *of this* Tractate.

IN this *Abstract* I ſhall only give you an account of what things are *Given* and what are *Required* in every *Plain*, and *Proportions* by which thoſe *Requiſites* are to be *found*, and not particular *Examples* in Numbers, as is already largely done, yet ſo, that the whole ſubſtance, in the general, may be ſeen in this at one view, and ſo I ſhall take them in order, beginning with

I. Vertical *or* Horizontal Plains, *Chap.* IX. *Fig.* I.

In theſe Plains there is nothing required but the Arch of the *Meridian* comprehended between the Pole of the World and the Plain, which is the *Latitude of the Place*, and is always given.

II. *The Erect Direct* South *and* North *Plains*, *Ch.* X. *Fig.* II *and* III.

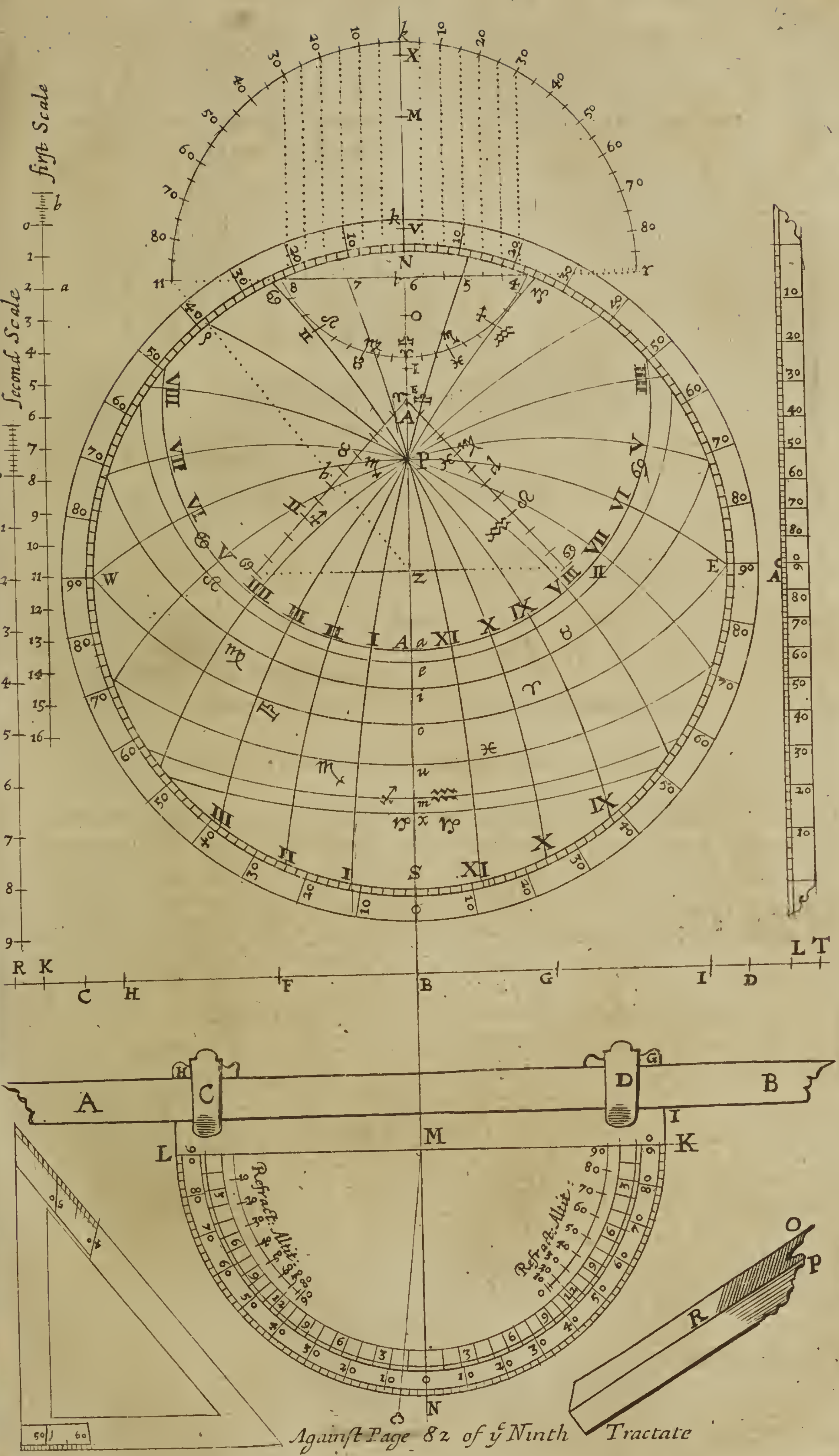
In theſe Plains alſo there is nothing required but the Arch of the Meridian, comprehended between the Pole of the World and the Plain, and this is always equal to the *Complement of the Latitude*, and ſo is alſo given.

III. *Erect Direct* Eaſt *and* Weſt Plains, *Chap.* XI. *Fig.* IV *and* V.

Over theſe Plains, neither of the *Poles* of the World is elevated, and therefore no Arch of the Meridian either given or required; but the Hour Lines being all Parallel, their diſtance may be contracted or enlarged anſwerable to the bigneſs of the Plain, and length of the Perpendicular Stile.

IV. North *and* South *Erect* Declining *Plains*, *Ch.* XII. *Fig.* VI *and* VII.

In theſe Plains two things are given, and three things muſt be ſought, before the Dial can be made — The things given are (1) The *Latitude* of the Place (2) The *Declination* of the Plain, — The things required are (1) The Arch of an Azimuth Circle between the Pole of the World and the Plain, and is called *The Height of the Pole or Stile above the Plain.*



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Plain. (2) The Arch of the Plain between the Meridian and the Substile, and is called, The *Deflection* or *Substiles Distance* from the *Meridian.* (3) The Arch of the Equinoctial Circle comprehended between the Meridian of the Plain, and the Meridian of the Place; and is called, *The Plain's Difference of Longitude.*

1. *For the Height of the* Pole *or* Stile *above the* Plain,

As the Radius,
To the Co-sine of the Plain's Declination:
So is the Co-sine of the Latitude,
To the Sine of the Stile's Height.

2. *For the* Deflection, *or Substile's Distance from the Meridian,*

As the Co-tangent of the Declination,
To the Radius:
So is the Tangent of the Stile's Height,
To the Sine of the Deflection.

3. *For the Plain's Difference of Longitude,*

As the Co-sine of the Latitude,
To the Radius:
So the Sine of the Deflection,
To the Sine of the Plain's Difference of Longitude.

V. *Direct* East *or* West *Reclining Plains*, *Chap.* XIV. *Fig.* IX.

In these Plains (as in upright Plains) two things must be given, and three required before the Dial can be made. — The Things given are (1) The *Latitude* of the Place. (2) The *Reclination* of the Plain. — The things required are the same as in upright declining Plains, namely (1) The Height of the Stile or Pole above the Plain. (2) The Deflection. (3) The Plain's difference of Longitude.

1. *For the Height of the Pole or Stile above the Plain,*

As the Radius,
To the Sine of the Latitude:
So the Sine of the Reclination,
To the Sine of the Stile's Height.

2. *For the* Deflection *or Substile's distance from the Meridian,*

As the Tangent of the Reclination,
To the Tangent of the Stiles Height:
So the Radius,
To the Sine of the Deflection.

3. *For the Plain's Difference of Longitude,*

As the Sine of the Latitude,
To the Radius:
So the Sine of the Deflection,
To the Sine of the Plain's difference of Longitude.

VI. *Direct*

VI. *Direct* South *Reclining Plains*, *Chap*. XV. *Fig*. X, XI, XII.

In these Plains, the Latitude of the Place and the Reclination of the Plain being given, there is nothing required but the Arch of the Meridian comprehended between the Pole of the World and the Plain, which is, *The Height of the Pole or Stile above the Plain*; and in these South Recliners it is thus found —— Substract the Reclination from the Complement of the Latitude, or the Complement of the Latitude from the Reclination, and the difference is the *Height of the Pole or Stile above the Plain*: And note,

If the Reclination be	Equal to	the Comp. of the Latitude, the	Plain is Equinoctial, as *Fig*. XV.
	Lesser than		South Pole is elevated.
	Greater than		North Pole is elevated.

VII. *Direct* North *Reclining Plains*, *Chap*. XVI. *Fig*. XIII, XIV, XV.

The Latitude of the Place, and the Reclination being known, there is nothing required in these Plains to be found, but the Arch of the Meridian between the Pole and the Plain, which is the *Stile's Height*. And in North Recliners it is thus found —— Add the Complement of the Latitude of the Place, and the Reclination of the Plain together, the sum of them (if under 90 deg. or the Remainder to 180 deg. if above 90 deg.) is the *Height of the Pole or Stile above the Plain*. But if the Sum or Aggregate be just 90 deg. it is a *Polar Plain*, as *Fig*. XIII and XIV.

VIII. South *Declining Reclining Plains*, *Chap*. XVII. *Fig*. XVI, XVII, XVIII, *and* XIX.

In these Plains three things must be given, and four things sought before the Dial can be drawn —— The things given are (1) The Latitude of the Place. (2) The Declination. And (3) The Reclination of the Plain. —— The things required are (1) The Distance of the Meridian and the Horizon, (2) The Height of the Pole above the Plain, (3) The Deflection, or Substile's Distance from the Meridian, (4) The Plain's difference of Longitude.

1. *For the Distance of the Meridian from the Horizon*,

As the Radius,
  To the Sine of the Reclination:
So the Tangent of the Declination,
  To the Co-Tangent of the Dist. Meri. and Horizon.

2. *For the Height of the Pole or Stile above the Plain*,

As the Sine of the Declination,
  Is to the Co-sine of the dist. of Mer. and Horizon:
So is the Radius,
  To a Fourth Sine.

If this Fourth Sine be equal to the Co-Latitude, the Plain is an Equinoctial Decliner; but if it be lesser than the Co-Latitude, substract it from the Co-Latitude, noting the Remainder. Then say,

As the Sine of the Arch last found,
  To the Sine of the Reclination:
So is the Sine of the Remainder before found,
  To the Sine of the Height of the Pole above the Plain.

3. *For*

3. *For the Deflection, or Substile's Distance from the Meridian,*
As the Co-Sine of the Stile's Height;
To the Radius:
So the Sine of the first Remainder,
To the Co-sine of the Deflection.

4. *For the Plain's Difference of Longitude;*
As the Sine of the first Remainder
To the Sine of the Deflection:
So is the Radius,
To the Sine of the Plain's difference of Longitude.

IX. *North Declining Reclining Plains, Chap.* XVIII. *Fig.* XX, XXI, XXII.

In these North Recliners Declining Plains, the same three things must be given, and the same four things sought, as were in South Recliners Declining. And they are thus found:

1. *For the Distance of the Meridian and Horizon,*
As the Radius,
To the Tangent of the Declination:
So is the Sine of the Reclination,
To the Co-Tangent of the Meridian and Horizon.

2. *For the Height of the Pole above the Plain,*
As the Sine of the Declination,
To the Radius:
So Co-sine Dist. Meri. and Horizon,
To a Fourth Sine.

Unto this Fourth Sine add the Complement of the Latitude, and reserve the Sum: And say,
As the Sine of the Fourth Sine,
To the Sine of the Reclination:
So the Sine of the Sum last found,
To the Sine of the Poles Height above the Plain.

3. *For the Deflection, or Substile's Distance from the Meridian,*
As the Tangent of the Reclination,
To the Sine of the Fourth Arch before found:
So Tangent Pole's Height above the Plain,
To the Sine of the Deflection.

4. *For the Plain's Difference of Longitude,*
As the Sine of the Stile's Height,
To the Tangent of the Deflection:
So is Radius,
To the Tangent of the Difference of Longitude.

And thus have you in this one Chapter an *Epitome* of the whole Art of *Dialling*, performed by *Trigonometrical* Calculation.

The End of the First Tractate.

GEOMETRICAL DIALLING DEMONSTRATED.

SHEWING,

Several Ways, how to find the true Places of the Stile, Subſtile *and* Meridian; *As alſo how to draw the* Hour-Lines, *upon all Plain Superficies in their due Poſitions.*

The Second TRACTATE.

PROEME.

IN the fore-going *Tractate*, having largely inſiſted upon all ſorts of *Plains*, upon which *Dials* are uſually made, and ſhewed the Reaſon of each *Plain* deduced from the *Sphere*; I ſhall in this Second *Tractate* be more brief, ſhewing only how the Places of the *Stile*, *Subſtile* and *Meridian*, may be found upon all ſorts of *Plains*, ſeated in their true *Places* and *Poſitions*, and from them to draw the *Hour-Lines*. And therefore to ſay nothing of the *Horizontal*, Full *North*, *South*, *Eaſt*, or *Weſt Plains*, whether *Erect* or *Reclining*, I ſhall immediately begin with *Upright Declining Plains*, and from them proceed to *South* and *North Declining Reclining Plains*, giving but one *Example* of each kind.

CHAP. I.

How to find the Place of the Subſtile, Stile *and* Meridian, *and how to draw the* Hour-Lines *upon an* Erect Declining Plain.

Figure I. OUr Firſt Example ſhall be of an upright Plain declining from the South Eaſtward 30 deg. in the Latitude of 51 deg. 32 min.

Upon C, as a Center, deſcribe the Quadrant C A Q, and with the ſame diſtance of the Compaſſes, upon A, (which ſhall be the Center of the Dial) deſcribe an obſcure Arch of a Circle, and herein ſet off 38 deg.

deg. 28 min. the *Complement* of the *Latitude* of the *Place*, from C to L, and draw the Line A L, prolonging it to D: Alſo, ſet 30 deg. the *Declination* of the *Plain*, from Q to X, and draw the Line X C, prolonging it, if occaſion be. Then upon C, with the diſtance C D, deſcribe an occult Arch of a Circle, continuing it, till it concur with the Line X C extended in S: And from S let fall a Perpendicular upon the Line Q C extended in R.

Then make C Y equal to R S, and draw A Y for the *Subſtilar Line* of your Dial: Then upon Y, erect a Perpendicular Y G, making Y G equal to C R, and through G, draw A G for the *Stile* of your Dial.

Then ſetting one foot of your Compaſſes in Y, with the other take the neareſt diſtance to the *Stile* A G, and ſet that diſtance upon the *Subſtile* from Y to ⊙, So ſhall ⊙ be the Center of the *Equinoctial Circle*, and the Line G Y extended both ways, ſhall be a Tangent Line thereto.

Upon ⊙ as Center deſcribe the Semicircle D * F repreſenting one half of the *Equinoctial Circle*, which done, lay a Ruler from ⊙ to P, where the *Tangent Line* croſſeth the *Meridian* or Line of 12. And where the Ruler croſſeth the *Equinoctial Circle*, which is at *, there begin to divide the Semicircle into 12 equal parts. A Ruler laid from ⊙ at the Points ⊙ ⊙ ⊙, *&c.* to every of thoſe Diviſions ⊙ ⊙ ⊙, *&c.* the Center of the *Equinoctial Circle*, I ſhall cut the *Tangent Line* in the Points 5,6,7,8,9,10,11 on the one ſide, and at 1,2,3,4 on the other ſide of the Meridian. Laſtly, Lines drawn from the Center A, through theſe Points in the *Tangent Line*, ſhall be the true *Hour-lines* belonging to the *Plain*: And that the *Stile* and *Subſtile* are rightly placed, ſhall be thus *Demonſtrated.*

DEMONSTRATION.

The *Trigonometrical* Canon or Proportion for finding the *Subſtile's diſtance from the Meridian being, As the Radius, Is to the Tangent Complement of the Latitude; So is the Sine in the Plain's Declination; To the Tangent of the Subſtile's diſtance from the Meridian.*

Now A C being the *Radius*, C D is the *Co-tangent* of the *Latitude*, the Angle C A D being 38 deg. 28 min. by Conſtruction. And if the *Co-tangent* C D be made the *Radius*, it is manifeſt that the *Sine* of the Angle X C Q, the Declination ſhall be made thereby the *Tangent* of the *Subſtile's diſtance from the Meridian*, Y C.

In like manner it may be proved, that as the *Radius* C D, is to C D the Co-ſine of the *Latitude* A D C: So is R C, the Co-ſine of the *Declination*, to R C, the *Sine* of G A Y, which was to be Demonſtrated.

CHAP. II.

How to find the place of the Meridian, Stile and Subſtile, in Declining, Reclining Plains.

Example I. *of a South Plain* { *Declining East* 30 *deg.* 0 *min.* / *Reclining* —— 55 *deg.* 0 *min.* } *Lat.* 51 *d.* 32 *m.*

DRaw a right Line L G, repreſenting the Baſe of the Declining Reclining Plain; In any part thereof, as at X erect a Perpendicular, as X W for the *Vertical Meridian*, extending it to a ſufficient Length: Alſo draw another Line as Q S, parallel to L G, at any convenient diſtance. *Figure* II.

Upon

Upon X as a Center describe the Arch of a Circle, and thereon set 55 deg. (the *Plains Reclination*) from *a* to *b*, and draw the Line X *b*, extending it till it meet with the Line Q S in N.

Then upon A (as a Center) describe a small Arch *c d*, and upon it set off 30 deg. equal to the *Declination* of the Plain, and draw the Line A B, between the two Parallel Lines.

Then making X C equal to X N, draw the Line C B, so shall B be the Center of the Dial, and the Line B C the *Meridian of the Place*, or Home Line of 12.

Also, make A M equal to A B, and upon M (as a Center) describe an Arch of a Circle *e f*, and upon it set 51 deg. 32 min. the Latitude of the Place from *f* to *e*, and draw the Line M *e*, extending it till it cut the Perpendicular Line X W in Z.

Likewise, make A K equal to A X, and A D equal to A N, and draw the Line K D, till it cut the Line X W, and prolonging it farther if need require.

From Z, let fall a Perpendicular to K D, in H, and taking the length K H in your Compasses, apply that distance from B (the Center of the Dial) to R in the *Vertical Meridian*; and draw the Line B R for the *Substile*.

Lastly, from the Point R, upon the Line B R, erect a Perpendicular, as R E, making R E equal to Z H, and from B to E, draw B E for the *Stile* of the *Dial*.

Now this Line R E being produced both ways shall be a *Tangent* to the *Equator*, whose Semidiameter must be equal to a Line let fall perpendicularly from R to the Stile, and that distance taken and set upon the Substile from R, shall be the Centre of the *Equator*, which being divided, and Points found in the Tangent Line, the rest of the *Dial* may be finished according to the usual manner.

Note I. If the Point D fall *just* into the Point Z, the *Plain* passeth through the *Pole*, and the *Plain* is a *Polar Plain*, and so it will do in a *South Plain Declining* 30 deg. and *Reclining* 34 deg. 32 min. in the Latitude of 51 deg. 32 min.

Note II. If the Point D, fall *above* Z, the Plain passeth between the *Zenith* and the *Pole*, and the *South Pole* is Elevated, and so it will do in a *South Plain* Declining 30 deg. and Reclining 20 deg. in the Latitude of 51 deg. 32 min.

Note III. If the Point D fall *below* Z, the Plain passeth between the *Pole* and the *Horizon*, (as in this Example) and the *North Pole* is Elevated.

Note IV. That although there will be considerable variation in the *Schemes*, by which these several *Varieties* of *Declining*, *Reclining Plains* are drawn; yet the construction will be the same, for sometimes the Point H, which here falls on that side of the *Vertical Meridian* which is next to S, in a *South Plain Declining* 30 deg. and *Reclining* 20 deg. will fall on the other side thereof towards Q. Likewise the *home of* 12, that is B C, which falls here between the *Substile* and the *Horizontal Meridian*, B A, would in such a Plain as I last mentioned fall between the *Axis* and the *Substile*.

Note V. As the *Reclination* of any *Plain* increases, the Points N, C and R all approach nearer to A, and when the *Reclination* is 90 deg. they are all Co-incident, and so vanisheth into an *Horizontal Dial*, whose *Substile* will be B A. And if the *Declination* be increased, at length the Points B and M, will be Co-incident, and the *Dial Plain* will be parallel to the *Prime Vertical*, and the *Dial* a *South Dial* whose *Substile* may be Z A.

DEMON-

DEMONSTRATION.

The Center B is taken at pleaſure, in any part of the *Horizontal Meridian*: For the Parallels Q S, and L G, might be nearer or farther off, only the *Diagram* would be *greater* or *leſſer* accordingly.

Now becauſe X C is equal to X N, the Face of the Reclining Plain X N ſhall cut the *Vertical Meridian* X W, and let it cut in the Point C.

And becauſe the Line B C ſubtends both the *Meridians* B A and A C, and is drawn upon the Plain from the Center, it ſhall repreſent the *Meridian of the Place*: For the Sun enlightning the Point C, at 12 a Clock in the *Vertical* X W, and at the ſame time the Point B, in the *Horizontal Meridian* A B, it ſhall at the ſame time illuminate the whole Line B C, ſo as the *Stile* of the Dial ſhall ſhadow the ſame juſt at the ſame time.

Again, becauſe the Triangles A N X and A K D are equiangular and equal: If the point W be the *Zenith*, (the point X ſuppoſed to be laid upon the point K) the Lines K D and X N will be equal, and the Angle A K D, equal to the *Reclination*: K D ſhall then truly repreſent the *Reclining Plain*.

Moreover, A M, being equal to A B by conſtruction, and the Angle A M Z, equal to the Latitude, the point Z repreſents a *Pole* of the *Equator*, becauſe the *Axis* M Z, and the *Meridian* A Z, meet there.

If therefore from the *Pole* Z, a *Meridian* Z H, do fall upon the *Plain* K D (or the back ſide thereof) at right Angles; it ſhall fall upon a point of the *Subſtile* in H, which point H, doth therefore limit the *Subſtile* on that part.

But the *Horizontal Line* in which B, the Center of the Dial is taken, muſt limit it on the other part alſo, to wit, in the point X, or K, ſo that H K is the juſt length of the *Subſtile* upon the *Plain*.

And becauſe the *Subſtile* muſt both paſs through the Center B, and incline to the *Vertical* X W (to which the Plain it ſelf inclines) the Line B R, equal to K H, being ſo placed, is the Subſtile.

Laſtly, Becauſe Z H is the neareſt diſtance between the *Pole* and the *Plain*, E R being equal thereunto, and perpendicular to the Subſtile, it ſhall be the length of the *Stile*, that is (where the *Subſtile* B R is *Radius*) the *Tangent* of the height of the *Pole* above the *Plain*, which is all which was to be proved.

CHAP. III.

Example II. Of the North Plain $\left\{\begin{array}{l}\textit{Declining--}60\\ \textit{Reclining--}16\end{array}\right\}$ *Latit.* 51 *d.* 32 *m.*

AS in the former Example, ſo in this; Firſt, draw a right Line at pleaſure as F Q, which ſhall repreſent the *Baſe* of the Plain. *Figure* III.

Aſſume any Point therein as B, from which Point erect a Perpendicular B Y, extending it both above and below the *Baſe Line* F Q.

Unto F Q, draw another right Line Parallel thereunto, at any convenient diſtance, as P M.

Then upon B, as a Center, deſcribe an Arch of a Circle C *b*, and upon it ſet

 60 deg.

60 deg. (the *Plain's Declination*) from C to *b*, and draw the Line B *b*, extending it till it meet with the Parallel P M in A.

Again, upon C, a Center describe another little Arch, as *a c*, and upon it set 16 deg. (the *Plain's Reclination)* from *a* to *c*, and draw the Line C *c*, extending it, till it concur with the Base Line F Q in D.

Take in your Compasses the Distance between C and D, and set that distance upon the Perpendicular Line B Y, from C to E, so that E be the *Center* of your Dial, and a Line drawn from E to A, shall be the *Meridian of the Place*, and Hour-line of 12.

Upon D, as a Center, describe an Arch of a Circle *d e*, and upon it set off 38 deg. 28 min. the *Complement* of the *Latitude*, from *d* to *e*, and draw the Line D *e*, extending it, till it meet with the perpendicular Line B Y extended downwards in Z. Then,

Prolong the Line A B, and make B K equal to B Z. and, through the Point K, draw the Line K U parallel to Z Y, cutting the Base Line F Q in S. And make B L equal to S K.

From L, let fall a Perpendicular to D C, *viz.* L O, and make H G equal to C O.

Then from E, the *Center* of the Dial, through G, draw the right Line E G for the *Substilar* Line of the Dial.

Also, upon the Line E G, from the point G, erect a Perpendicular, and make it equal in length to the Line L O, as the Perpendicular G N: Then a Line drawn from the Center E, through N, shall be the *Stile* of the Dial.

And thus have you all the Requisites belonging to this *Reclining Plain*; and if you take the least distance from the point G, to the *Stile* N E, and set that distance upon the *Substilar Line* from G to ⊙; the point ⊙ shall be the *Center* of the *Equinoctial Circle*, and the Line N G extended both ways shall be a *Tangent* thereto, by which the Dial may be finished according to the usual way.

DEMONSTRATION.

Because the Angle A B C, (to which the Angle K B Z is equal) is equal to the *Plain's Declination*: Therefore the Line K B A is the *Horizontal Meridian* upon the Bases P M and F Q. And B K is equal to B Z by construction, and the Triangles D B K and D B Z are equi-angled and equal, having one common *Side* D B, and a common *Angle* B D Z, and B K is equal to B Z: Therefore a right Line passing from K in the *Horizontal Meridian* to D, or E in the *Vertical Meridian* Z Y, shall represent the Axis of the Equator; for the Angle B D K equal to B D Z is the *Complement* of the *Latitude*, by construction, and D B Z a right Angle.

And therefore, whensoever the point K, is either shaddowed or enlightned, the point A is the same, and the point E also, because it is in the same *Axis* with K, is at the same time so affected; wherefore, the *Center* of the *Dial* being at E, a Line drawn from thence upon the *Plain* to A, shall be the *hour* of 12.

And because the *Hypotenusa* D K, or EK, is the *Axis* passing from E, in the *Reclining Plain* by K in the *Horizontal Meridian*, and the point K being in the Line K S H G, a Perpendicular let fall from thence to the *Plain*, shall fall in the same Line K S H G.

Make

Make C Y equal to H G, which is alſo equal to C O: then a Perpendicular from L to X, is the ſame with that from L to O, namely the Line L O.

And becauſe B L is equal to S K, and C X to H G, therefore a Perpendicular let fall from K to G, ſhall be equal to L X, or L O.

And becauſe K (as hath been ſhewed) is a *Point* in the *Axis*, and G a *Point* in the *Dial Plain*, the Perpendicular K G, or L O ſhall be the *height* or *length* of the *perpendicular Stile* N G: or more properly the *Tangent* thereof, E G being made *Radius*. And the point G, where it cuts the *Dial Plain* at right Angles, ſhall be a point in the *Subſtile*.

But E or D is the *Center* of the *Dial*, as hath been already proved; Therefore, a Line drawn from E to G, that is, the Line E G, is the *Subſtile*.

And becauſe G N, being equal to L O, and the Angle E G N is a right Angle; therefore, the Line E N, drawn by the points E and N is the *Stile*.

> Enough is here written to ſhew how to find the *Meridian*, *Stile* and *Subſtile*, in all *Declining* and *Reclining Plains*; In which this is worth the obſerving, that by the *Precepts* here delivered, not only the *Requiſites* and their *Magnitudes* or *Quantities* are found; but their true *Places* and *Situations* upon the *Plains* alſo, all which are obvious together in the very working, or with a very little tranſpoſition made ſo. And for that reaſon, I have here made choice of *Two* ſuch *Examples* as are before in the firſt Tractate made uſe of, and the work of them performed by other means, that ſo the coherence may be the more obvious, both which *Examples* you will find in the 18*th* and 19*th*. *Chapters* of the preceding *Tractate*.

From the Precepts before delivered, it may be *Noted*, That as the *Reclination* may increaſe, the Points N, E and R, all approach ſtill nearer to A; and when the *Reclination* is 90 deg. they are all Co-incident. and Vaniſh into an *Horizontal Dial*, whoſe *Subſtile* is B A.

In like manner, if the *Declination* be ſtill increaſed, at length the Points B and M, will be Co-incident, and the Dial Plain will be parallel to the *Prime Vertical* Circle, and the Dial a *South Dial*, whoſe *Subſtile* may be Z A.

But whether the *Declination* increaſe or not, if the *Reclination* amount to 70, or above 70 degrees: Then the *Subſtilar* Line applied (as before) from B to the *Vertical* Z X, it ſhall fall between the points A and X, upon the *Baſe* of the *Plain*. And by this means the former *Precepts* may be rendred inſufficient, or (at leaſt) inconvenient in ſuch Caſes.

And for theſe Reaſons I have added what follows in the next Chapter.

CHAP.

CHAP. IV.

A Second Geometrical Way *to find the* Requisites *belonging to* Declining Reclining Plains, *agreeable to the* Calculatory *way before delivered in the First* Tractate: *and thereby Demonstrated.*

OUr *Example* here shall be of a *South Plain, Declining Eastward* 30 deg. and *Reclining* from the *Zenith* 55 deg. which is the *Example* of the *Third Variety* of *South Declining Reclining Plains* in the First *Tractate*, *Chap. XVII.*

Wherein let it be required to find	*deg.*	*min.*
1. The *distance* of the *Meridian* and *Horizon*	64.	41
2. The *height* of the *Pole* or *Stile* above the *Plain*	19.	25
3. The *distance* of the *Substile* from the *Meridian*	6.	02
4. The *Plain's* difference of *Longitude*	17.	38

I. *For the Distance of the Meridian and Horizon.*

Figure IV With 60 deg. of a Scale of *Chords* describe the *Quadrant* A B D: and upon A, erect the Perpendicular A R, which shall be a *Tangent* Line thereto. Then,

1. Take 30 deg. the Plain's *Declination*, and set it from A to E; Also take 55 deg. the *Reclination* and set it from D to G, and from E to G, let fall the Perpendiculars E M and G H; and through E and G draw two right Lines from B, extending them till they cut the Tangent Line in the Points F and R: —— So shall G H be the *Sine*, and A R the *Tangent* of 35 deg. equal to the Complement of the *Plain's Reclination:* —— Also E M shall be the *Sine*, and F A the *Tangent* of 30 deg. equal to the Plain's Reclination.

2. Make A I equal to H L, A Ruler laid from B to I, will cut the Quadrant in K: So is K D the *distance of the Meridian from the Horizon*, namely 64 deg. 41 min.

Demonstration from *Trigonometrical Calculation.*

As the whole Sine (or *Radius*) A B 90 deg.
Is to B H, the Sine of the Reclination 55 deg.
So is A F the Tangent of the Declination 30 deg.
To A I, the Tangent of the Arch A K 25 deg. 9 min.
Whose Complement is the Arch D K 64 deg. 41 min. the distance of the Meridian and Horizon.

II. *For the height of the Pole or Stile above the Plain.*

1. Extend the Line M E, till it cut the Line B R in P, and make A N equal to M P: So is A N the Tangent of the Arch A *, which measured upon the Chords will be 31 deg. 14 min. Which Arch being less than the Latitude of the Place 51 deg. 32 min. Substract it therefrom; so will the remainder be 20 deg. 18 min.

2. Set

2. Set 20 deg. 18 min. the Arch laſt found from A to Q, and draw the Line Q C perpendicular to A B —— Alſo make B S equal to Q C —— B O equal to B R —— And B W equal to B M —— So ſhall B S be the Sine of 20 deg. 18 min. the Arch laſt found —— B W the Sine of 60 deg. the Complement of the Declination —— and B O the Sine of 64 deg. 41 min. the diſtance of the Meridian from the Horizon.

3. Take in your Compaſſes the diſtance B S, and ſetting one foot in O, with the other deſcribe an obſcure Arch of a Circle *a a*, and from B, draw a Line B *m*, which may only touch the top of the ſame Arch, which done, ſet one foot of the Compaſſes in W, and with the other take the neareſt diſtance to the Line B *m*, which diſtance ſet from B to V; and draw the Line V T parallel to A B, ſo ſhall T A meaſured upon the Scale of Chords be 19 deg. 25 min. for the height of the Pole or Stile above the Plain.

Demonſtration from *Trigonometrical Calculation.*

(1.) As the whole Sine (or *Radius*) A B 90 deg.
Is to B M (the Sine of the Complement of the Plain's Declination) 60 deg.
So is A R (the Tangent Complement of the Reclination) 35 deg.
To A N (the Tangent of the Arch A *) 31 deg. 14 min.
Which Arch being taken out of the Latitude 51 deg. 32 min. leaves 20 deg. 18 min. which is an Arch of the Meridian of the Place intercepted between the Plain, and the Pole of the world.

(2.) As the Sine B O (the diſtance of the Meridian and Horizon,) 64 deg. 41 min.
Is to the Sine B S (the Arch laſt found) 20 deg. 18 min.
So is the Sine B W (the Complement of the Plain's Declination) 60 deg.
To the Sine B V (whoſe Arch A T is the *height of the Pole or Stile above the Plain.*)

III. *For the Subſtile's Diſtance from the Meridian.*

Take B V the Sine of the Stile's height 19 deg. 25 min. and ſetting one foot in D, with the other deſcribe the Arch *c c*, and from B, draw the right Line B *o* only to touch the top of the Arch *c c* —— Then ſetting one foot of your Compaſſes in S, with the other take the leaſt diſtance to the Line B *o*, this leaſt diſtance ſet from B to Y and through Y draw Y X parallel to A B, ſo ſhall B Y be the Sine, and A X the Arch or Chord of 6 deg. 2 min. and is the diſtance of the Subſtile from the Meridian.

Demonſtration from *Trigonometrical Calculation.*

As the Sine of B V (the height of the Pole above the Plain) 19 deg. 25 min.
Is to the *Radius* B D (90 deg.)
So is the Sine of B S (the Arch of the Meridian between the Pole and the Plain) 20 deg. 18 min.
To B Y (the Sine of A X) 6 deg. 2 min.
Which is the Subſtile's diſtance from the Meridian.

IV. *For the Plain's Difference of Longitude.*

Take B S and set it from B to Z, so is B Z the Sine of 20 deg. 18 min. (the Arch of the Meridian between the Pole and the Plain.) ----- Also take B Y, the Sine of 6 deg. 2 min. (the height of the Pole above the Plain.) And setting one foot in Z, with the other describe the Arch *n n*: Lay a Ruler to B, and this Arch *n n*, and draw an obscure Line thereby, till it cut the Quadrant in Æ: So shall A Æ be 17 deg. 38 min. for the Plain's Difference of Longitude.

Demonstration from *Trigonometrical Calculation: For,*

As the Sine of Z B (the Arch of the *Meridian* between the Pole and the *Plain*) 20 deg. 18 min.
Is to the whole Sine (or *Radius*) A B 90 deg.
So is the Sine Y B (the Substile's distance from the Meridian) 6 deg. 2 min.
To the Sine of the Arch A Æ, 17 deg. 38 min.
Which is the *Plain's Difference* of *Longitude*.

CHAP. V.

How by the Help of an Horizontal Dial *in any* Latitude, *to draw the* Hour-Lines, *find the Place of the* Stile *and* Substile *for any* Upright Declining Plain *in the same* Latitude.

Figure V. OUr *Example* shall be of an *Upright Plain Declining* from the *South* towards the *West* 30 deg. in the *Latitude* of 51 deg. 32 min.

First, draw a right Line R T, representing the *Base* or *Horizontal Line* of the *Declining Plain*.

Secondly, In this Line, assume any Point, as A, and from it draw another right Line A S, making the Angle S A T, equal to 30 deg. the *Plain's Declination*: Which Angle must be made towards the *Right* hand of A, if the Plain decline *Westward* (as here it doth) or towards the *Left* hand if the Plain decline *Eastward*.

Thirdly, Upon this Point A, erect a Perpendicular to the Line R T, for the *Meridian* Line of the *Declining Plain*; ------- And (from the same point A) another perpendicular to the Line A S, for the *Meridian* of the *Horizontal Dial*.

Fourthly, In any part of this last Perpendicular, assume any Point at pleasure, (as X,) and make that the Center of an *Horizontal Dial*, and upon it describing a Circle, set thereon the Hour-arches proper for an *Horizontal Dial* for your Latitude (namely of 51 deg. 32 min.) at the marks * * *, *&c.*

Fifthly, From the Center X, which is the Center, and the several Points * * *, *&c.* draw right Lines, extending them till they concur or meet with the Horizontal Line of the Declining Plain R T first drawn, at the Points 9, 10, 11 and 1, 2, 3, 4, 5, *&c.*

Sixthly, Upon the Center X, make the Angle A X P, equal to the Latitude, 51 deg. 32 min. and draw the Line X P, cutting the Line A S in P.

Seventhly, Make A Z equal to A P, so shall Z be the *Center* of the *Declining Dial*.

Eighthly,

Fig : I.

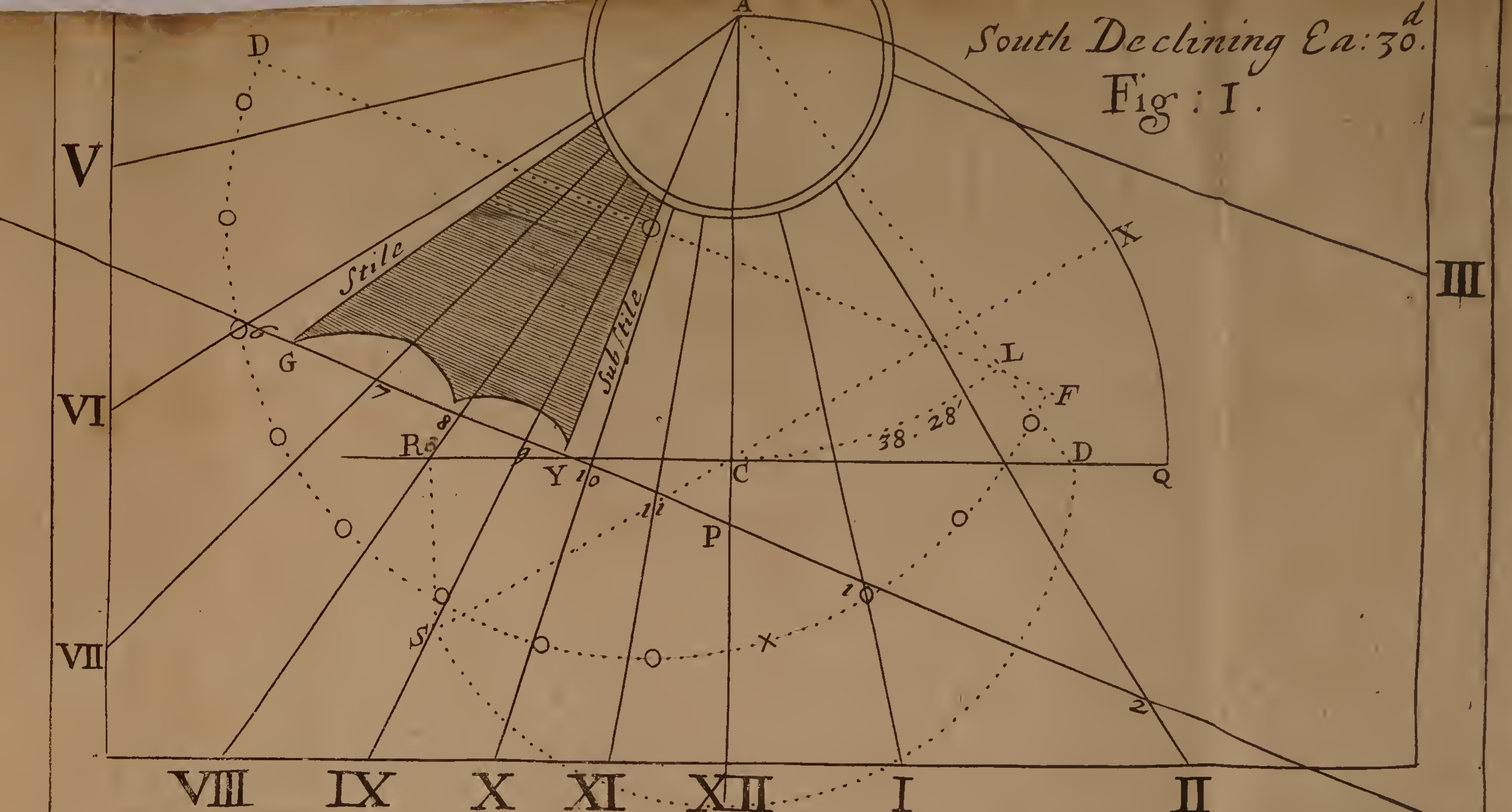


Fig : II.

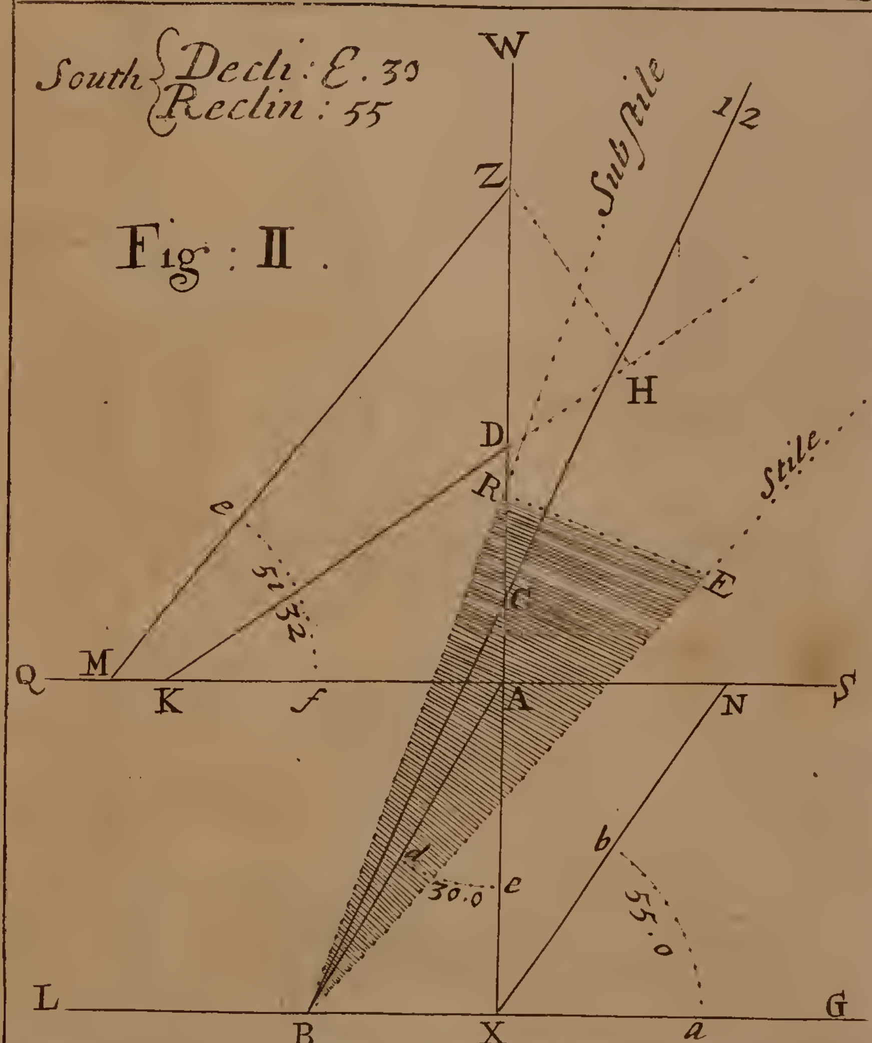


Fig : III.

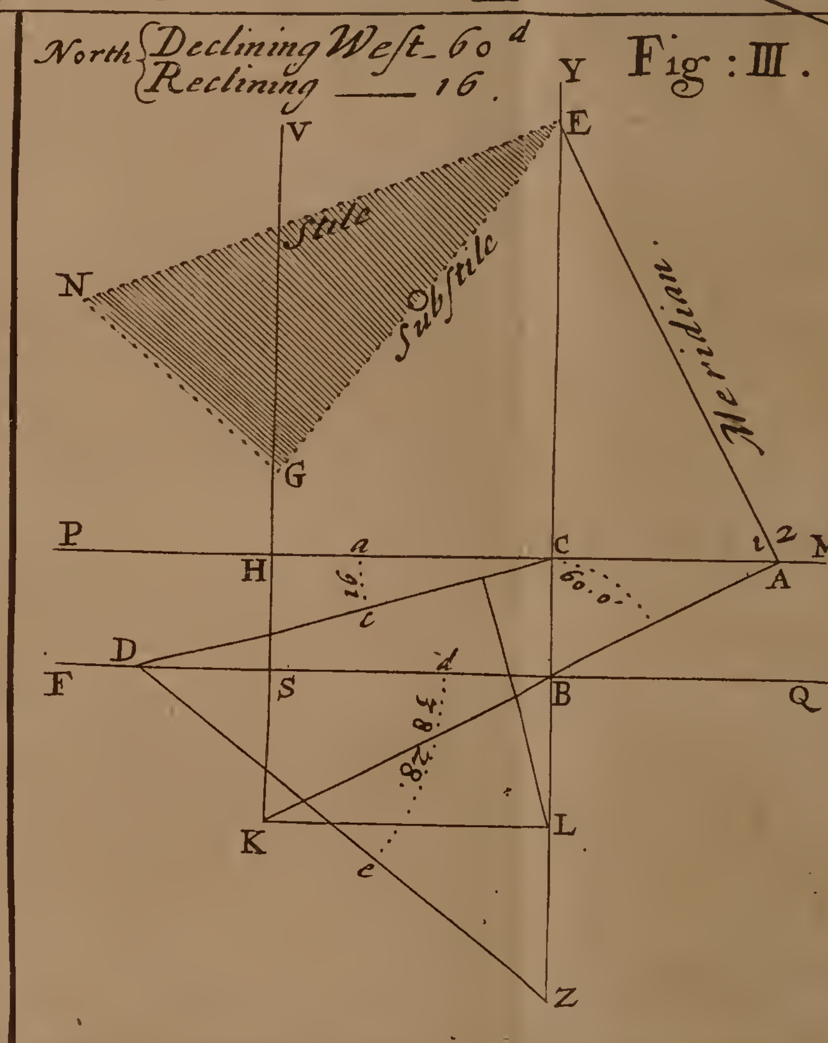


Fig : IV.

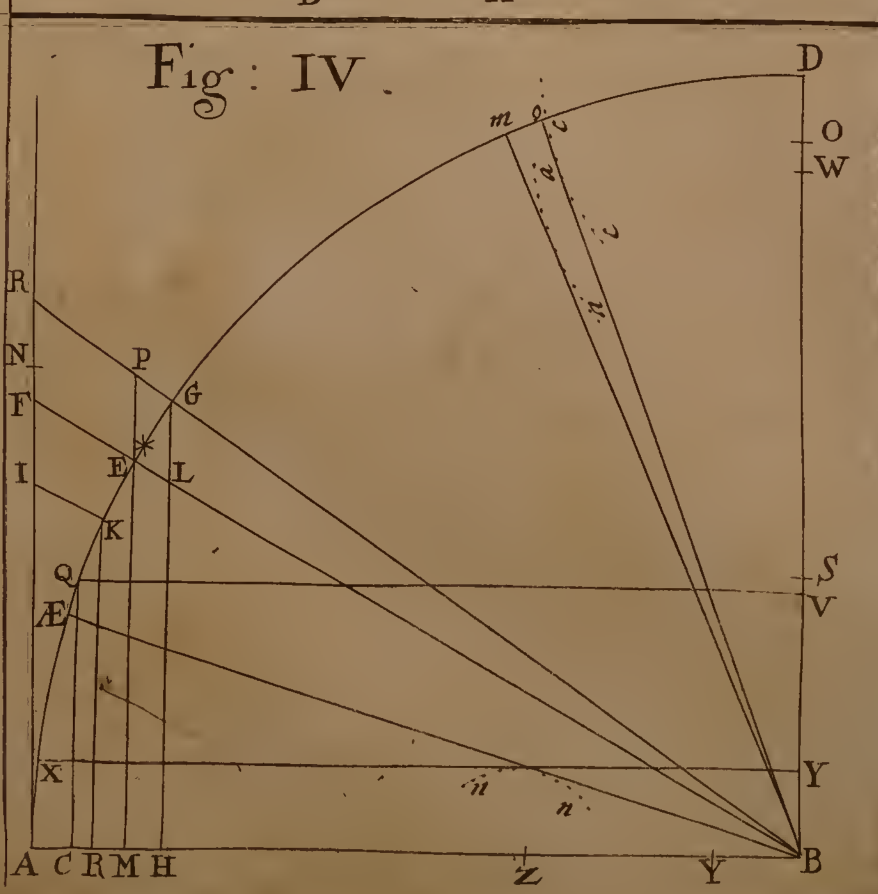
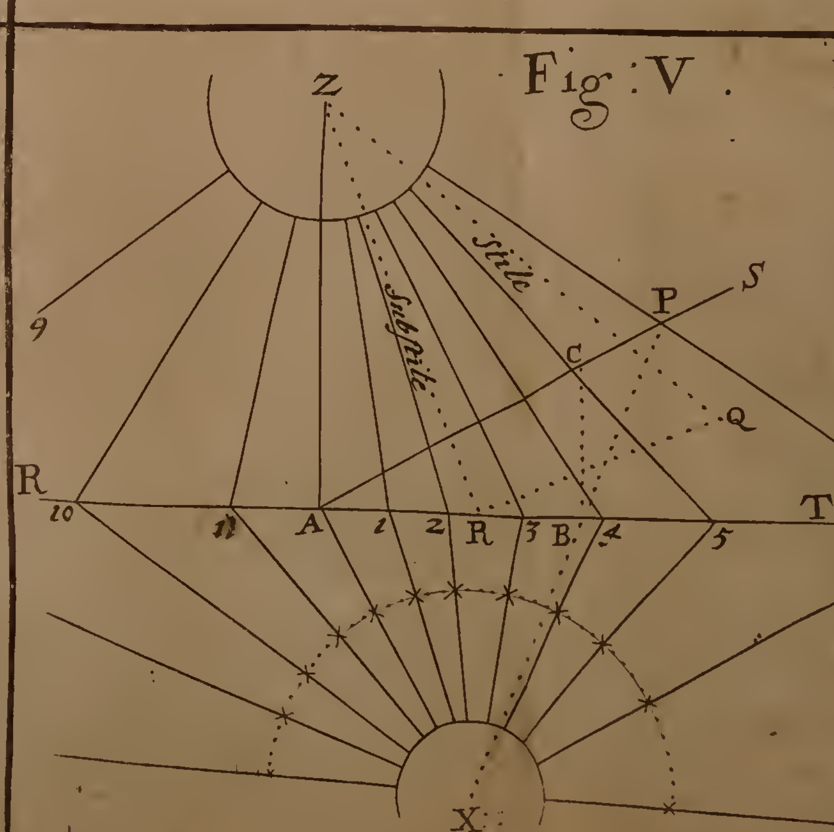


Fig : V.



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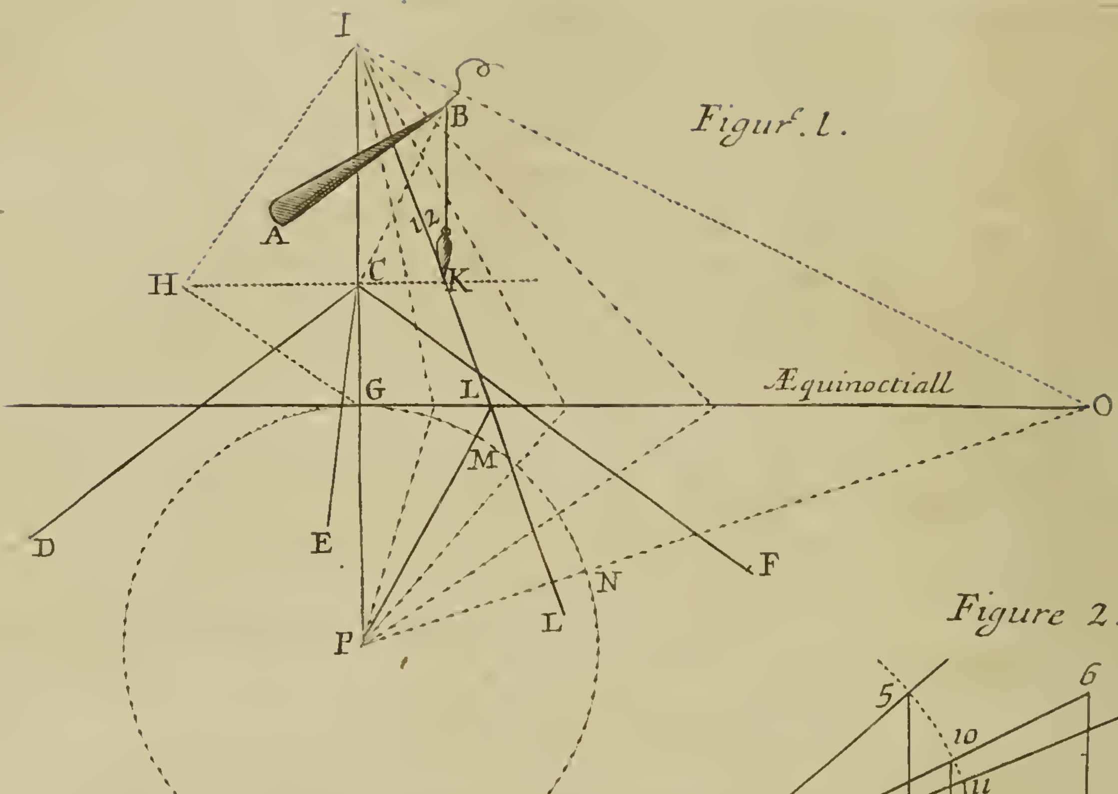
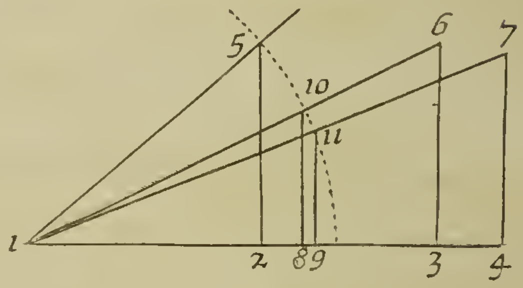
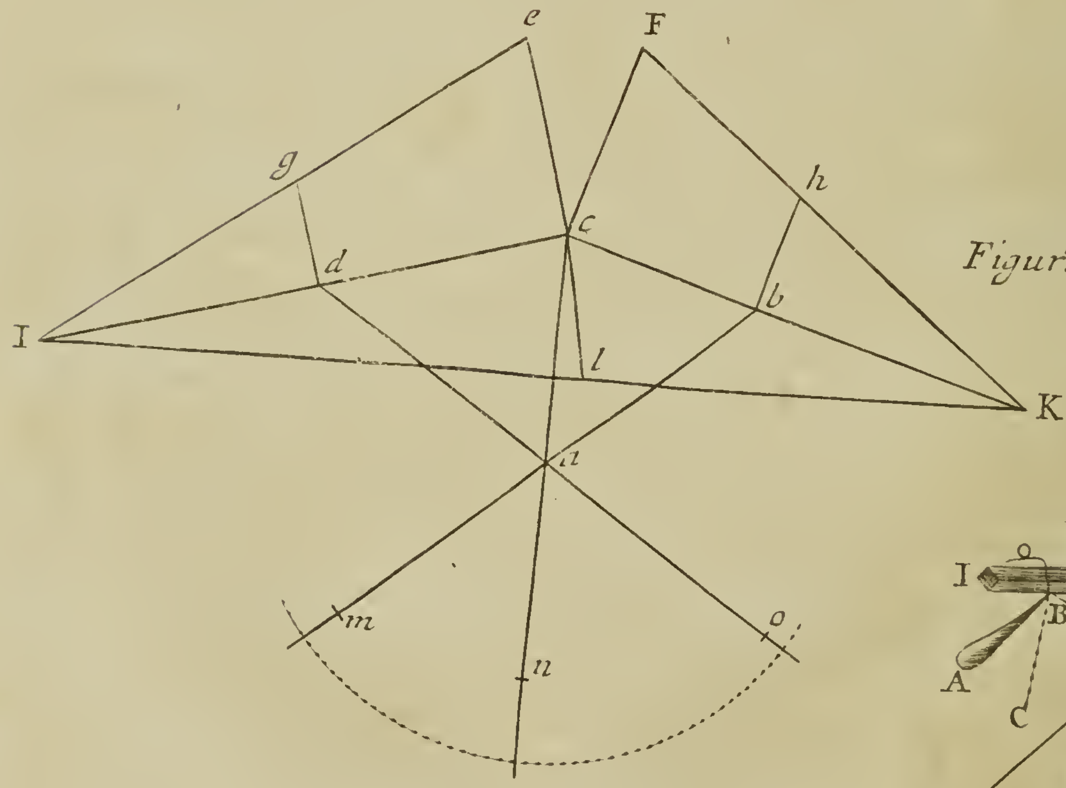


Figur. 1.

Figure 2.





Figur. 3.

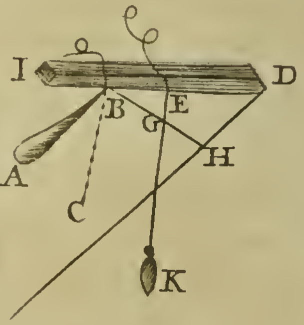


Figure 4.

Eighthly, Upon the point B, (where the Line X P cutteth the Horizontal Line of the Declining Plain, R T) erect a Perpendicular, cutting the Line A S in C.

Ninthly, Make A R, equal to B C and draw the Line Z R, for the *Substile* of the *Declining Dial.*

Tenthly, From the point R, erect a Perpendicular to the Line Z R, making R Q equal to A B, and draw the Line Z Q for the *Stile* of the *Declining Dial.*

Lastly, If from the Center of the Declining Plain Z, you draw right Lines to the several points 9, 10, 11 and 1, 2, 3, *&c.* (where those *Hour-lines* of the *Horizontal Dial* did concur with the *Horizontal Line* of the *Declining Plain* R T,) those Lines shall be the true Hour-lines belonging to your Declining Plain: And so is your Dial finished; and the Stile and Substile in their due Places.

If Any shall think this Chapter deficient for want of Demonstration, let them know, that the Demonstration belonging to the First Chapter of this Tractate, doth Demonstrate this also.

CHAP. VI.

A Third Geometrical *Way of* Dialling: *Shewing, The Manner how to inscribe the* Substile, Stile, *and* Meridian-line *in all* Plains.

SECT. I. Definitions.

BY the Angle of *Declination* is understood the Arch of the *Horizon* intercepted between the *Plain* and the *East* or *West* point toward which it declineth.

By the Angle of *Erection* is understood the Arch of a *Vertical Circle* intercepted between the Plain and the Horizon toward the depressed Pole; which in our Northern Hemisphere is the *South* Pole. Wherefore the *Plains* which lean toward the elevated Pole (which by others are called *North* inclining, and *South* reclining) have evermore their Angle of Erection greater then a quarter of a Circle. And such Plains as are upright or perpendicular on the Plain of the Horizon, are said to be erected 90 deg.

SECT. II.

In Horizontal Dials the Meridian-Line is directly drawn *North* and *South*: and it is also the Substile, and the Stile hangeth over it at an Angle equal to the Elevation of the Pole.

SECT. III.

In *North* and *South* upright Plains the Six-a-Clock-Line is drawn parallel to the Horizon, and the Meridian-Line is to be drawn perpendicular to it; and the Meridian-Line is also the Substile: over which the Stile is to hang a an Angle equal to the Complement of the Elevation of the Pole.

SECT. IV.

SECT. IV.

In *North* and *South* Plains which ſtand not upright but bowing, the Six-a-Clock-Line alſo is parallel to the Horizon. And the Meridian-Line is perpendicular thereto; being alſo the Subſtile. But the Angle which the Stile maketh with it is thus found out. Add the Angle of Erection to the Height of the Pole, and the Aggregate thereof ſhall be the Angle of the Stile's Altitude to be accounted from the upper end of the Meridian in *South* Plains, but from the lower end in *North* Plains.

If the Aggregate be juſt 90 deg. the Plain is parallel to the Æquinoctial. If it be juſt 180 deg. the Plain is parallel to the Sixth Horary Circle, and conſequently to the *Axis* of the World: and hath therefore no Center. If it exceed 180 deg. ſubduct 180, and the Arch remaining ſhall be the Altitude of the contrary Pole.

For it is to be noted that in our *Northern* Hemiſphere in all kind of *North* Dials the *North* Pole is elevated, and the Stile pointeth upwards from the Center: and in all kind of *South* Dials the *South* Pole is elevated, and the Stile pointeth downwards; except in ſuch caſes wherein it is required otherwiſe.

SECT. V.

East and *West* Plains are parallel to the Meridian or Twelfth Horary Circle; and conſequently to the *Axis* of the World: and have therefore neither Center nor Meridian-Line. And in them the Substile is a Line drawn up toward the *North* from a Line parallel to the Horizon, at an Angle equal to the Elevation of the Pole: and is therefore parallel to the *Axis* of the World.

CHAP. VII.

A general way for the Inſcription of the Subſtile, Stile *and* Meridian, *in all Declining* Dials.

Figure I. DRraw a long line parallel to the Horizon, and note the *East* and *West* ends thereof: croſs it with a perpendicular line, being the Diameter, deſcribe a Semicircle that way toward which the Declination is either *East* or *West*. Then beginning at the upper end of the Diameter if the Plain ſtand *Southward*, or elſe at the lower end, if it ſtand *Northward* (but contrarily in the *Southern* Hemiſphere) reckon upon the Semicircle theſe three Arches, namely the Elevation of the Pole, the Declination of the Plain, and the Erection thereof. To the end of each of theſe Arches draw a Line out of the Center A, But the Line of the Declination muſt be extended beyond the Center. Take alſo on the firſt line the point B toward the Semicircle where you ſhall ſee convenient: and through the point B draw a Line parallel to the Diameter, cutting the Line of erection in E, and the Line of the Pole's Altitude in C. Then on the Line of Declination beyond the Center meaſure A P equal to B C, and through the point P draw a long line parallel alſo to the Diameter called therefore the ſecond parallel. Alſo from the point E draw a long line for the Horizon parallel to A B, cutting the line of Declination in D, the Diameter in G, and the ſecond parallel in F.

Again

Again from the Center A upon the Diameter toward the contrary end to that where you began to reckon the three Arches, meaſure A L equal to A E, and through L draw the Prohorizon parallel alſo to A B, cutting the ſecond parallel in H, and thereon meaſure L M equal to D G directly under it: Draw A M for the Meridian-line.

Laſtly, on the Line of Erection meaſure A N equal to P F, and from the point N draw the Line N O parallel to the Diameter: and on the ſecond parallel from the point H meaſure H S toward the Horizon equal to N O, And from the Center draw A S for the Subſtile, over which the Stile muſt ſtand perpendicularly having at S the height of the line A O, wherefore upon the point S erect the Line S Z perpendicular to the Subſtile and equal to the Line A O, and from the Center draw A Z for the Stile, ſo that the angle Z A S ſhall be the height of the Stile above the Subſtile.

Note that if the point P fall not between the Horizon and the Prohorizon, the contrary Pole ſhall be elevated, and therefore the Subſtile and Stile ſhall be drawn forth on the other ſide of the Center, as it is done in the ſecond Figure.

And if the point P fall on the Horizon, the Plain is parallel to ſome one Meridian Circle, and conſequently to the *Axis* of the World, and hath therefore no Center. An example of this kind (becauſe it is miſtaken by many Writers of the Art of Dialling) is here after ſet down.

And if the Declining Plain be upright or erected 90 deg. the Horizon ſhall be the Line A B, and the Prohorizon ſhall be drawn parallel to it at the diſtance of the Line A B, and the point S ſhall fall upon the point H, upon which the Stile ſhall have height equal alſo to P F. And the Line or Diameter A L ſhall be the Meridian.

If the Arch of Declination chance to be ſo great, that the point D, being the concurrence of the Line of Declination with the Horizon, will will not fall with your Paper, you may find out the Angle L A M for the drawing of the Meridian Line, thus.

Draw a Line $\alpha\,\varepsilon$ as in *Fig.* I. touching the Semicircle in the Diameter: and thereon meaſure $\alpha\,\lambda$ equal to the ſine $\gamma\,\theta$: then draw the Line $\lambda\,\mu$ parallel to the Line of Declination. Laſtly, out of the Center draw A μ: So have you the Angle λ A μ ſought for.

CHAP. VIII.

II. *The manner how to inſcribe the reſt of the* Hour-lines.

TAke the point R any where upon the Subſtile formerly inſcribed; and through it draw a long line perpendicularly T R V for the Contingent line: and where the Contingent line croſſeth the Meridian line, note that point with the letter K. Then meaſure the neareſt diſtance of the Stile from the point R, and ſet R Q upon the Subſtile equal to it: Q ſhall be the Center of the Æquinoctial Circle: deſcribe therefore the Æquinoctial Circle of what bigneſs you will upon the Center Q. And laying your Ruler upon the Center Q and the point K, the Interſection of the Meridian and Contingent lines, draw the Line Q K X cutting the Æquinoctial Circle in X. This Line Q K X is the Meridian line of the Æquinoctial, at which you muſt begin to divide that Circle. Divide it therefore (beginning at X) into 24 parts. *Figure* III.

 Then

Then applying your Ruler unto the Center Q and each of those Divisions which are in the two Quadrants of the Æquinoctial next to the Contingent line, where in every place your Ruler cutteth the Contingent, make there obscure Pricks. And out of A the Center of the Dial through each of those obscure Pricks draw fair long lines for the Hour-lines. And by continuing those Hour-lines through the Center you may fill up the whole 24 Hours.

But if the Dial have no Center, the Hour-lines must be drawn parallel to the Substile: and the height at which the Stile shall hang parallel above the Substile, shall be equal to the space between the Contingent line, and the Center of the Æquinoctial, that is equal to Q S.

The Hour-lines being drawn must be noted with their proper figures beginning at the Meridian, or Noon, or 12 a-clock-line: and from thence setting down the morning Hours on the *West* side; and the afternoon Hours in order on the *East* side. And the Dial will be more artificial and seemly if you omit all those Hours which serve not for use at some time of the year.

Figure IV. Now concerning such Dials in which the point P falleth on the Horizon (an example whereof is in the second figure following) although the point M falleth upon S, yet the Substile (by reason of the obliquity of the Plain of the Meridian unto the Plain of the Dial) shall be distracted from the 12 a-clock-line: In which case you shall find out the Meridian of the Æquinoctial thus, Through the point γ, in which the Line of the Erection cutteth the Semicircle, draw $\gamma\,\delta$ parallel to the Diameter, then with your Compasses take $\zeta\,\eta$ the Sine of the Complement of the Elevation of the Pole, and setting one foot in γ with the other foot describe $\varkappa$ in the Line A B, and thereunto draw the Line $\gamma\,\varkappa$. Then upon the Æquinoctial Circle from the Substile measure out the Angle A Q X equal to the Angle $\varkappa\,\gamma\,\delta$, downward if the Plain be *South*, but upward if it be *North*. And so shall you have Q K X the Meridian of the Æquinoctial, whereat you must begin to divide that Circle.

The example in *Fig.* III. may serve for all Dials having Centers: if withal you remember that in such Dials which have the same Line both for the Meridian and Substile, the same Line also is the Meridian of the Æquinoctial, which you must begin to divide.

The example in *Fig.* IV. may serve for all Dials having no Centers: if withal you remember that in Dials parallel to the Plain of the Sixth Horary circle, the same Line is the Substile, and the Meridian both of the Dial and of the Æquinoctial. And that in *East* and *West* upright Dials the Meridian of the Æquinoctial is that Diameter thereof, which is parallel to the Contingent line.

The End of the Second Tractate.

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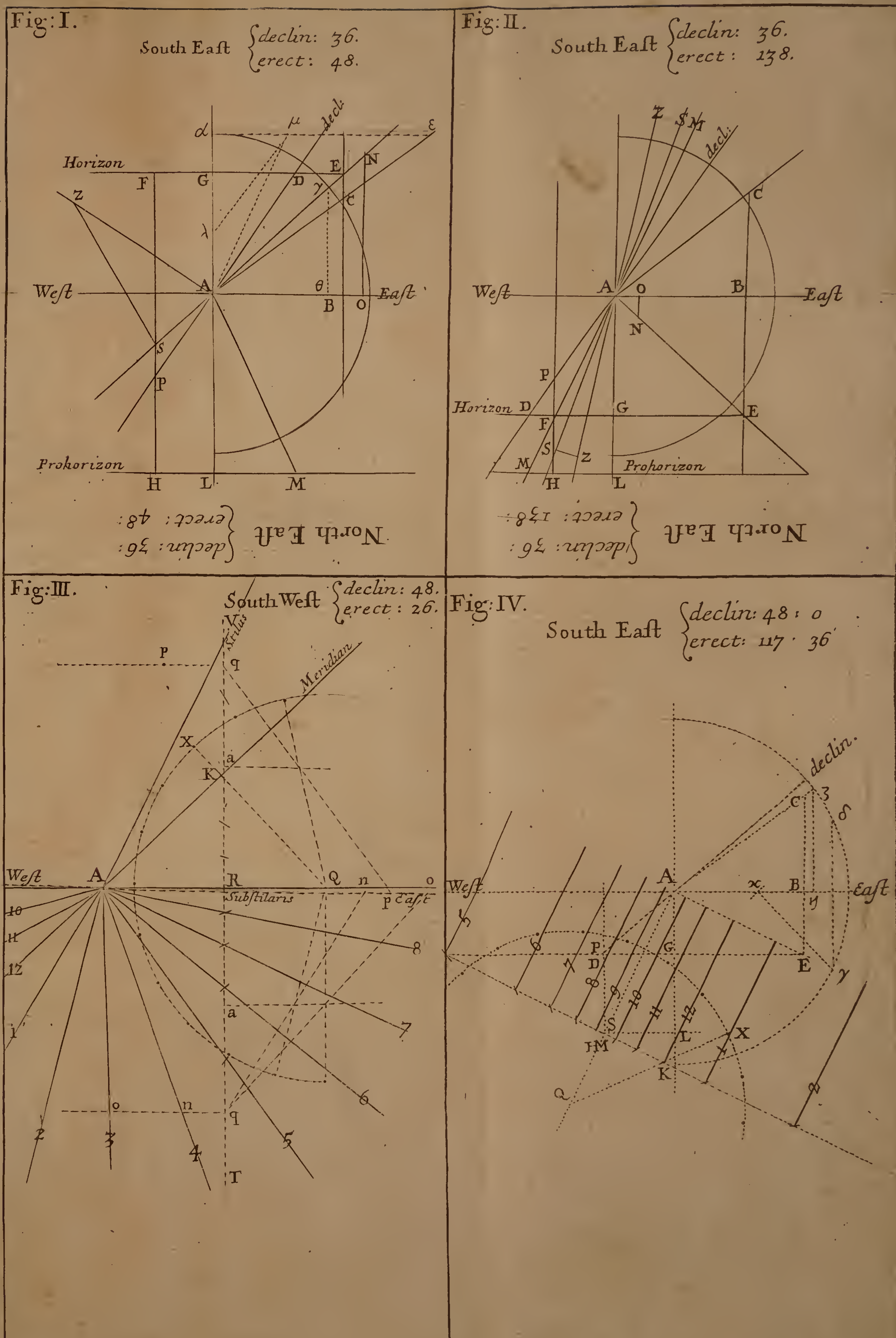

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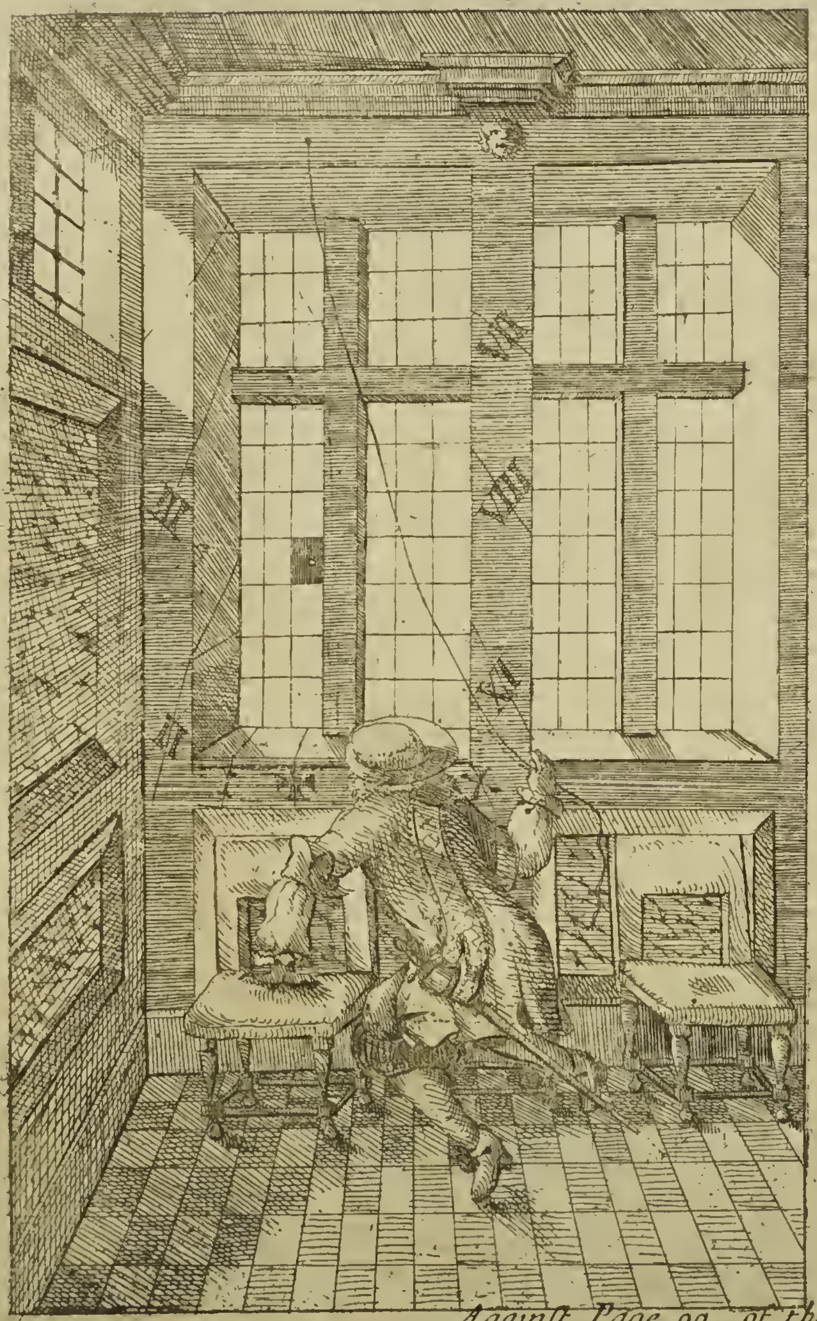

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INSTRUMENTAL DIALLING

Performed by

SCALES of *Natural* SINES & TANGENTS.

Shewing (by an easie *Artifice*) in any *Latitude*, how *Hour-Lines* may be described upon all kind of *Plain Superficies*; by Referring all *Declining Reclining Plains*, to *New Latitudes* and *New Declinations*; where they shall become only *Upright Decliners*.

AND

How the same *Work* may be performed, by *Trigonometrical Calculation*, by the CANONS of *Artificial* SINES & TANGENTS.

The Third TRACTATE.

PROEME.

IN this *Tractate* I shall be very brief, the manner of making of *Sun-Dials* by help of these *Scales* being very easie to perform, and no less delightful to put in Practice: And, the manner of working being (almost) the same in all *Cases*, I shall not need to give *Examples* in all Varieties of *Plains* but in *One* or *Two*, which will be sufficient for all *Cases*. For one *Example* may very well serve for all *Vertical* or *Horizontal*, all *Direct North* and *South Plains*, whether *Erect*, *Reclining* or *Inclining*: And another *Example* of an *Upright Plain*, *Declining* from the *North* or *South*, towards the *East* or *West*: For all other *Plains*, as *Direct East* or *West Recliners* or *Incliners*; as also of all *North* and *South Recliners* or *Incliners*, which *Decline* also; Those (by the *Artifice* delivered in this *Tractate*) may be Reduced to a *New Latitude*, and a *New Declination* in that *Latitude*, where they shall stand as *Upright Declining Plains*. And, forasmuch, as all *Instrumental* ways (at the best) are subject to some inconveniencies in many *Cases*, I have therefore also framed *Canons*, whereby this *Artificial* way of *Referring Declining Reclining Plains* to *New Latitudes* and *New Declinations*, where they may stand as *Upright Plains*, may be performed by *Trigonometrical Calculation*, by the *Canons* or *Tables* of *Artificial Sines* and *Tangents*.

CHAP.

CHAP. I.

Of Vertical or Horizontal, as alſo of Direct North or South Erect, or Reclining and Inclining Plains, how to deſcribe Hour-Lines upon them.

WHat theſe ſeveral *Plains* are, hath been already ſhewed in *Chap* 3. *Tractate* I, And that there is nothing in all theſe Plains required to be known before *Hour-lines* can be drawn upon them, but the *Latitude* of the Place and *Reclination* or *Inclination* of the *Plain:* And how that may be attained is alſo ſhewed at large in the 14th and 16th Chapters of the Firſt Tractate. And therefore to paſs by the finding of thoſe things I will immediately proceed to *Examples.*

Suppoſe therefore, that a Direct *South Plain,* in the *Latitude* of 32 deg. ſhould *Recline* from the *Zenith* 28 deg.

By the forementioned *Chapters,* the Height of the Pole above ſuch a Plain, would be found to be 30 deg. For 28 deg. the Reclination of the Plain being Subſtracted from 58 deg. the Complement of the Latitude, the Remainder will be 30 deg. and ſo much is the Pole Elevated above the Reclining Plain. Which known; the Dial may be made as followeth.

Figure I. 1. Draw two right Lines, one for the Meridian, and Hour-line of 12; the other for the Horizon, and Hour-line of 6; croſſing at right Angles in O, the Center of the Dial.

2. In all theſe *Horizons,* Direct *North* or *South Plains,* whether *Erect, Reclining* or *Inclining,* Take [always] 90 deg. out of the Scale of *Sines,* (or 45 deg. out of the Scale of *Tangents,* which is equal thereto) and ſet that diſtance upon the Meridian Line, from O, the Center of the Dial, to X.

3. Out of the Scale of Sines alſo, take the height of the Pole above the Plain (in this *Example* 30 deg.) and ſet them from O to A, and from O to B, and draw the Lines A X and B X.

Figure II. 4. For the finding of the Hour-points, you muſt draw a right Line as C E D, and taking 45 deg. from your *Tangent Scale,* with that diſtance, upon E as a Center, deſcribe the Semicircle C F D: Alſo, from your Scale of Tangents take 15. deg. (or one hours Equinoctial Diſtance,) and ſet them from E to II, likewiſe, take 30 deg. and ſet them from E to I. And at E ſet E III. —— In like manner, the whole Hour-ſpaces E III: E II: E I, being thus pricked down upon the Line E D, you may inſert between them the Equinoctial Diſtances for the Halves, and Quarters of Hours, by taking 3 deg. 45 min. for one Quarter, 7 deg. 30 min. for half, and 11 deg. 15 min. for 3 quarters of an Hour, out of your Tangent Scale, and ſetting them from E to 1 2 3 for the quarters of that Hour —— Alſo 18 deg. 45 min. — 22 deg. 30 min. and 26 deg. 15 min. will divide the Space between the Hour-points of I and II into Quarters alſo —— And Laſtly, 33 deg. 45. min. — 37 deg. 30 min. and 41 deg. 15 min. will divide the Space between the Hour-points of I and D into Quarters likewiſe: And ſo is your *Semicircle,* or *Hour-Scale* E D, rather, divided.

And

And here Note, That this *Semicircle*, or *Hour-Scale* being thus prepared, it is ready to find the Hour-points, not only in these *Direct Plains*, but in all upright *Declining Plains* also —— And now let us proceed to finish the Dial.

5. Take in your Compasses the length of the Line A X or B X, and set that distance upon the Semicircle from D to *a*, and draw the Line C *a*.

6. Set one foot of the Compasses in the Hour-point of I, in the Line E D of the Semicircle, and with the other take the least distance to the Line C *a*, which set upon the Lines A X and B X, from X to 5 and from X to 7, and also from A to 11, and from B to 1. —— Again, Set one foot of your Compasses in the Hour-point of II, in the Line E D of the Semicircle, and with the other take the nearest distance to the Line C *a*, and set that distance upon the Lines A X and B X of the Dial, from X to 4, and from X to 8: and also from A to 2 and from B to 10. —— Lastly, the least distance taken from E (or III the third Hour-point in the Semicircle) to the Line C *a*, must be set upon the Lines A X and B X from X to 9, and from X to 3.

7. Lines being drawn from O, the Center of the Dial, through the respective Points 1, 2, 3, *&c.* 11, 10, 9, *&c.* they shall be the true Hour-lines belonging to the Reclining Plain.

8. Lastly, The Stile must stand upon the Meridian Line O X (which is also the Substile) making therewith an Angle of 30 deg. and so is the Dial finished.

Note, In the same manner as you found the Points for the whole hours, by taking the least distances from the hour-points of I. II and III, to the Line C *a*; So may Points for the Halves and Quarters of Hours be found by taking of the least distances from the Points 1, 2, 3 to the same Line C *a*.

CHAP. II.

Of Upright (or Erect) Declining Plains, *and how to find the Place of the* Stile *and* Substile; *and to describe* Hour-Lines *upon such Declining* Plains *in any* Latitude.

LEt it be required to describe *Hour-Lines*, and to find the place of the *Stile* and *Substile* upon an *Upright Plain*, *Declining* from the *South* towards the *East* 20 degrees, in the *Latitude* of 46 deg.

1. Draw a right Line perpendicular to the *Horizon* for the Meridian of the Place, and Hour-line of 12. Towards the upper part thereof, if the Plain behold the South, as here it doth (or towards the lower part thereof if the Plain had beheld the North) assume any point, as G, for the Center of the Dial. *Figure* III.

2. Out of your Scale of *Tangents* take 46 deg. the Latitude of the Place, and set them from G to H. Also, from the same Scale take 44 deg. the Complement of the Latitude, and set them from G to Q and from H to K, making G Q and H K perpendicular to G H, and then draw Q K which will be parallel and also equal to G H.

3. From the Scale of *Sines* take 20 deg. the Plain's Declination, and set

them from H to L, and from Q to R, through which points, draw G L for the *Subſtile* of the Dial, and G R for the *Hour-line* of *Six*, which Hour-line of *Six* you muſt draw quite through the Center of the Dial.

4. Take 70 deg. the Complement of the Plain's Declination, out of the Scale of Sines, and ſet them from G to 12, upon the Line G H, and from L to M, making M L perpendicular to G L; and, through M, draw G M for the *Stile* of the Dial.

5. Out of the Scale of Sines take 44 deg. the Complement of the Latitude, and ſet them upon the Line G Q, from G to P; and through P, draw a Line P 6 Parallel to G H, cutting the Hour-line of Six in *6*.

Figure II. 7. Take in your Compaſſes out of your Dial-plain the ſhorter Line 12. *6*, and repairing to your Semicircle, ſet it from D to *b*, and draw the Line C *b*.—— Alſo take the longer Line 12.*6*, and ſet it upon the Semicircle from D to *c*, and draw the Line C *c*,

8. From the Hour-point of I. in the Hour-ſcale, or the Semicircle, take the leaſt diſtance to the Line C *b*, and ſet that diſtance upon your Dial from 12 to 7, and from 6 to 11 —— Alſo take from the point II, the leaſt diſtance to the Line C *b*, and ſet that diſtance upon your Dial from 12 to 8, and from 6 to 10 —— And the leaſt diſtance taken from III or E, to the Line C *b*, muſt be ſet upon the Dial from 12, or *6*, to 9. And thus are Points for Six of the Hour-lines found. —— In like manner, take the leaſt diſtance from the Hour-point of I, to the Line C *c*, and ſet that diſtance upon the Dial from 12 to 5, and from *6* to 1. —— Alſo the leaſt diſtance from II to C *c*, muſt be ſet from 12 to 4; and from 6 to 2. —— And Laſtly, the diſtance from III or E, to C *c*, muſt be ſet from 12, or *6*, to 3. And ſo have you points for all the hours. —— Through which right Lines drawn from the Center, ſhall be the true Hour-lines required to be drawn.

In the ſame manner may the Halves and Quarters of Hours be inſerted; And for the Stile of the Dial it muſt ſtand Perpendicular upon the Subſtilar Line G L, making an Angle therewith equal to the Angle M G L. And ſo will your Dial be finiſhed.

CHAP. III.

Of Eaſt *and* Weſt *Reclining or Inclining Plains.*

THeſe *Eaſt* and *Weſt Reclining* and *Inclining* Plains may be deſcribed and drawn by the directions of the laſt Chapter; If firſt, you find out in what *Latitude* ſuch an *Eaſt* or *Weſt Reclining* Plain, will be an *Erect* or Upright Plain; And alſo, what *Declination* that *Upright Plain* ſhall have in that *New Latitude:* And in *Eaſt* or *Weſt Reclining* or *Inclining Plains* this *New Latitude* and *New Declination* may be eaſily found: For;

1. The *New Latitude* will be (always) the Complement of the *Old Latitude*. And;
2. The *New Declination* will be (always) equal to the *Complement* of the *Reclination* in the *Old Latitude.*

Example: Suppoſe, that a Direct *Eaſt* or *Weſt* Plain in the *Latitude* of 35 deg. ſhould *Recline* from the *Zenith* 26 deg. 30 min. In what *Latitude* will

this

this *East Reclining Plain* be an *Upright Plain?* And what *Declination* shall it have in that *New Latitude?*

1. The *Old Latitude* is 35 deg. the *Complement* whereof 55 deg. is the *New Latitude.*

2. The *Old Reclination* is 26 deg. 30 min. and the *Complement* thereof 63 deg. 30 min. is the *New Declination.* Wherefore;

If you make (by the directions of the last Chapter) an *Upright Dial*, Declining 63 deg. 30 min. in the Latitude of 55 deg. That Dial shall be the same with a *Direct East Dial Reclining* 26 deg. 30 min. in the Latitude of 35 deg.

Only this is to be remembred, That in all *Upright Plains* the *Hour-line* of 12 stands *Perpendicular* to the *Horizon*, and in all *East* or *West Recliners* the *Hour-line* of 12 must lie *Parallel* to the *Horizon.*

An *Example* of an *East* or *West Reclining Dial*, you have in the 14*th Chapter* of the *First Tractate*, Fig. IX.

Note moreover, that when the *New Latitude* and *New Declination* are found as before, the *Upright Dial* must be drawn to the *New Latitude* and *New Declination*, and not to the *Old.*

CHAP. IV.

Concerning North *and* South *Plains, which do both* Decline *and* Recline.

THe best way to describe *Hour-lines* upon these kind of *Plains*, will be:

1. To refer them to a *New Latitude* where they may be Upright Plains: And;
2. To find what *Declination* they shall have in that *New Latitude:* And;
3. To know how much the *Meridian* (or Hour-line of 12) must *ascend above*, or *descend below* the *Horizontal Line* of the *Reclining Plain:* And;
4. *Which way* (or to what *Coast*) that *Ascension* or *Descension* must be: And;
5. How the *Dial* (being drawn upon Paper, according to its *New Latitude* and *New Declination*) is to be transferred from the Paper Draught upon the Plain.

And to find these *Five Requisites*, and to transfer the Dial to the Plain, shall be the work of this Chapter.

Let it be required to find the Five forementioned *Requisites*, in a *South Plain* which *Declineth* from the *South Westward* 24 deg. 20 min. And *Reclineth* from the Zenith 54 deg.

I. *To find the* New Latitude.

1. Describe a Semicircle B D A, whose Diameter B A, let be made equal to 90 deg. of your *Scale of Sines*, or to 45 deg. of your *Scale of Tangents*, which is all one: Then: *Figure* IV.

2. Take

2. Take 36 deg. the Complement of the Plain's Reclination, out of your Scale of *Tangents*, and set them upon the Semicircle from B to D, drawing the Lines A D, and B D.

3. Take 65 deg. 40. min. the Complement of the Plain's Declination out of the *Scale* of *Sines*, and set them from A to C.

4. Set one foot of the Compasses in C, and take the nearest distance to A D, which distance set from A to E; so shall A E measured upon the *Scale* of *Tangents*, contain 33 deg. 30 min.

Note 1. In *South Reclining* Plains, (as this our Example is) this Tangent last found (*viz.* 33 deg. 30 min.) must be compared with the *Latitude* of the Place, 51 deg. 30 min. and their difference is 18 deg. whose Complement 72 deg. is the *New Latitude sought.*

Note 2. If the fourth Tangent last found had proved to be equal to your Latitude, the Plain would have been an *Equinoctial Plain:* If less than the Latitude (as here it is,) the contrary Pole (*viz.* the *North Pole*) is Elevated.

This Rule for *South Recliners.* But for *North Recliners,*

Note, That the Fourth Tangent last found, must be compared with the *Complement* of the *Latitude* of the Place; And if it prove to be equal thereunto, the Plain is a *Polar Declining Plain.* —— But if it be *greater* or *less* than the Complement of the Latitude, the difference between them is the *New Latitude.*

II. *To find the* New Declination.

Figure IV. 1. Take 36 deg. the Complement of the Plain's Reclination, out of the *Scale* of *Sines*, and set them from B to F, and draw the Lines B F and A F.

2. Take 24 deg. 20 min, the Plain's Declination, out of the *Scale* of *Sines*, and set them from A to G.

3. From the Point G, take the least distance to the Line F A, and set that distance from A to H; So shall the distance A H measured upon the *Scale* of *Sines*, contain 14 deg. 1 min. And so much is the *New Declination*, in the fore-found *New Latitude.*

Note, That the *New Declination* thus found, is [always] *less* in *Quantity* than the *Old Declination* was: But it is [always] to the *same Coast*, that is to say, from the *North* or *South*, towards either *East* or *West*, as the *Old Declination* was.

III. *To find the* Meridian Ascension *or* Descension.

Figure IV. 1. Take 24 deg. 20 min. The Plain's *Old Declination*, out of the *Scale* of *Tangents*, and set them from B to K, and draw the Lines B K and A K.

2. Take 54 deg. the Plain's Reclination, out of the *Scale* of *Sines*, and set them from A to L.

3. Take the least distance from L, to the Line A K, which distance set from A to M, and A M, measured upon the *Scale* of *Tangents* will give 20 deg. 6 min. for the *distance of the Meridian from the Horizon.*

IV. *To*

IV. *To find which way (or to what* Coaſt*) the* Meridian Line, Aſcending *or* Deſcending above *or* under *the* Horizontal Line *of the* Plain, *is to be drawn.*

The laſt *Section* of this Chapter taught how to find the quantity of the Angle which the *Meridian* makes with the *Horizontal* Line of the Plain: Now it reſteth to let you know, to what *Coaſt*, it muſt be drawn, and alſo whether it muſt be drawn to aſcend above, or deſcend below the Horizontal Line of the Plain: For which take theſe

General Rules.

In North Incliners. South Recliners.	Leſs than Equinoctial, the Meridian muſt be drawn,	above below	That end of the Horizontal Line, which lies contrary to the Coaſt of the Plain's Declination.
	More than Equinoctial, the Meridian muſt be drawn,	below above	That end of the Horizontal Line, which lies the ſame way with the Coaſt of the Plain's Declination.
In North Recliners. South Incliners.	Leſs than a Polar, the Meridian muſt be drawn,	above below	That end of the Horizontal Line that looks the ſame way with the Coaſt of the Plain's Declination -- And this Meridian thus drawn in North Recliners, repreſents 12 at Midnight.
	Equal to a Polar, the Meridian muſt be drawn below the Horizontal Line at that end which is contrary to the Coaſt of Declination, and the Six of Clock Hour-Line is always the Subſtile.		
	More than a Polar, the Meridian muſt be drawn,	below above	And from that end of the Horizontal Line, which lies contrary to the Coaſt of the Plain's Declination --- And in South Incliners it is only ſerviceable to help to draw the reſt of the Dial.

V. *How the* Dial *(being made according to the* New Latitude *and* New Declination) *is to be transferred from the Paper-Draught, upon the Plain.*

Having drawn an *Horizontal Line* upon your Dial Plain, in the moſt convenient part thereof, and made choice of a Point therein for the Center of your Dial, apply the Center of your Paper Draught to this Center, moving the Paper Draught about, till the *Meridian Line* of the Paper Draught do make an Angle with the *Horizontal Line* drawn upon the Plain, equal to what you found it to be by the Third *Section* of this *Chapter*, and to its proper *Coaſt* as you found it ſhould, by the *Fourth Section* hereof, then (if you have not erred in any of your former workings) will the *Stile* of your *Paper Draught*, (or rather a pattern thereof cut out in Paſt-board) being placed upon the *Subſtile* of your Paper Draught, have direct reſpect to the *Elevated Pole*. And thus, due reſpect being had to what is here delivered, you may eaſily transfer the *Subſtile* and the reſt of the Hour-lines to the Plain, putting thereon ſo many as the Plain is capable to receive at any time of the year: And leaving out ſuch as may be ſuperfluous.

¶ From this way of making of *Declining Reclining Dials* by transferring them to a *New Latitude* and a *New Declination* where they may be *Upright Declining Plains* only, it will ſometimes ſo fall out, that this *New Declination* may be very *great*, and then, the beſt way to draw ſuch Dials will be by the Directions given in the 13*th* Chapter of the Firſt Tractate. —— Alſo, ſometimes the *New Latitude* will be very *great*, and ſometimes very *ſmall*, and then the Precepts for finding of the Place of the *Subſtile*, *Stile* and *Hour-line* of *Six* in the Second *Chapter* of this *Tractate*, will, in ſuch Caſes, be thought inſufficient, or (at leaſt) inconvenient; To remedy which the following Chapter is added.

CHAP. V.

How to find the Place of the Subſtile, Stile, Hour-line *of* Six, &c. *in all* Upright Declining Plains, *in ſuch* Latitudes *where the* Pole *hath either* very Small *or* very Great *Elevation.*

WHereas the *Precept* delivered in the Second Chapter hereof, will be only convenient in theſe Middle Latitudes; namely, between 30 and 60 deg. Yet by the referring *Declining Reclining Plains* in One *Latitude* to *Upright Decliners* only, in another *Latitude*, that *New Latitude* will ſometimes fall out to be either very *Great* or very *Small*, and how to deal with upright *Declining Plains* in ſuch *Latitudes* ſhall be here taught.

I. *Where the Latitude is but* Small.

Suppoſe that a *Declining Reclining Plain*, in ſome one Latitude, being referred to a *New Latitude* and *New Declination*, the *New Latitude* ſhould be found to be 20 deg. and the *New Declination* 30 deg. To find the Place of the *Subſtile*, *Stile*, *&c.* (the Latitude being but *Small*, *viz.* 20 deg.) proceed in manner following.

1. Draw

1. Draw a right Line A B 12, for the Meridian and Hour-line of 12, in which Line make choice of a Point convenient for the Center of your Dial, as A. *Figure* V.

2. Out of your *Scale* of *Tangents* take 45 deg. (for the *Radius*) and ſet them from A to C, drawing the Line A C at right Angles to the Meridian Line A 12,——Alſo, Take 20 deg. (the Latitude) out of your *Scale* of *Tangents*, and ſet them from A to B,——Then make CD equal to AB, and B D equal to AC, conſtituting the right angled Parallelogram A B C D, and drawing the Diagonal Line C B.

3. Out of your *Scale* of *Sines*, take 30 deg. (the Plain's *Declination*) and ſet them from B to E, and draw the Line A E for the *Subſtile* of the Dial.

4. Through the Point E, draw the Line E K parallel to C B, cutting the Line C D in K, and through the Point K, draw the Line A K for the Hour-line of Six, extending it through the Center of the Dial on the oppoſite Side of the Plain.

5. Upon the Point E, erect a Perpendicular to the Line A E, and out of your *Scale* of *Sines*, take 60 deg. (the Complement of the Plain's Declination) and ſet them from A to 12, and from E to F, drawing the Line A F for the Stile of the Dial.

6. Take 70 deg. (the Complement of the Latitude) out of your *Scale* of *Sines*, and ſet them from A to H, and draw the H *m*, parallel to A B, cutting the Hour-line of Six in *6*; And make A *6*, above the Center of the Dial, equal to A *6* below the Center; and draw the Lines 12. *6* and 12. *6*.

7. Laſtly, if you take theſe two Lines 12.*6* and 12.*6* in your Compaſſes, and put them into your Semicircle (or Hour-Scale, Figure III) you may divide them therefrom as before in Chapter 2, at the Points 5, *6*, 7, 8, 9, 10 and 11. And alſo at 1, 2, 3, 4 and 5. Through which Points Lines being drawn they ſhall be the true Hour-lines.

II. *Where the Latitude is* Great.

If a Declining Reclining Plain being referred to a New Latitude, that New Latitude ſhould be found to be 70 deg. in ſuch Great Elevations of the Pole, work as followeth.

1. Draw a right Line for the Meridian, and Hour-line of 12, as ART, aſſuming the Point A for the Center of the *Declining Dial*. *Figure* VI.

2. Out of your *Scale* of *Tangents* take 45 deg. (or the *Radius*) and ſet them from A to B.

3. Take 20 deg. the Complement of the Latitude, out of the Scale of Tangents, and ſet them from A to C, and from B to D, and draw the Line CD, conſtituting the Right-angled Parallelogram A B C D.

4. Out of your *Scale* of *Sines*, take 30 deg. (the Plain's Declination,) and ſet them from B to R, and from C to G; and draw the right Line G R, cutting the Line B D in E —— Then draw the Line A E for the *Subſtilar* Line of your Dial, and A G for the *Hour-line* of *Six*; which continue thro' the Center of the Dial A.

5. Take 60 deg. (the Complement of the *Plain's Declination*) out of the *Scale* of *Sines*, and ſet them from G to P (upon the Line C D continued) and from R to T, and from A to 12.

6. Draw a right Line, through the Points T and P, extending it till it cut the Line B D (that being alſo extended) in the Point O.

7. Upon the Point E, erect a Perpendicular to the Line A E, making EF equal to E O, and draw A F for the Stile of your Dial.

8. Take

8. Take 20 deg. (the Complement of your Latitude) out of the *Scale* of *Sines*, and set them from A to H, and draw the Line H 6 parallel to A B, cutting the Hour-line of *Six* in *6*.

9. Make A *6* above the Center, equal to A *6* below the Center, and draw the Lines 12.*6* and 12.*6*.

Lastly, These two Lines 12.*6* and 12.*6* being put into the Semicircle (or Hour-Scale *Fig. II.* you may divide them in the Points 5.*6*.7.8.9.10.11 and 1.2.3.4 and 5. So Lines being drawn from A, through those Points, shall be the true *Hour-lines* for the *Declining Reclining Plains*, it being referred to this *New Latitude* and *New Declination.*

CHAP. VI.

How the Work of the Fourth Chapter is to be performed by Trigonometrical Calculation, *by the Tables of* Artificial Sines *and* Tangents.

THE best of *Instrumental* Operations are subject to inconveniencies in some Cases; and therefore I have added this *Chapter*, shewing how the Work of the Fourth *Chapter* may be performed by *Calculation*, which of all other ways must have the preheminence: And that the harmony there is between *Instrumental Operation* and *Arithmetical Calculation* may the plainer appear, I will take for an Example, the same Example of a *Declining Reclining Plain*, that is in the forementioned Fourth *Chapter*, *viz.*

South { *Declining West* 24 *deg.* 20 *min.* / *Reclining*—— 54 *deg.* 00 *min.* } *Latitude* 51 *deg.* 30 *min.*

I. *To find the New Latitude.*

As the *Radius*, 90 deg.	10.000000
Is to the Co-sine of the Old Declination 65 deg. 40 min.	9.959596
So is the Co-tangent of the Reclination 36 deg.	9.361261
To the Tangent of 33 deg. 30 min.	9.820857

Note 1. In *South Recliners* (as this Example is) this Fourth Tangent found, *viz.* 33 deg. 30 min. must be compared with your *Latitude*, and the *Complement* of their *Difference* in the *New Latitude* sought for: So this 33 deg. 30 min. being Substracted from the Latitude 51 deg. 30 min. the Remainer 18 deg. is the *NEW LATITUDE.*

Note 2. If this Fourth Tangent prove to be *Equal* to your *Old Latitude*, the Declining Reclining Plain will be an *EQUINOCTIAL PLAIN.*

Note 3. If the Fourth Tangent prove to be

More / *Less* } than the *Old* / *Latitude* the { *North* / *South* } *Pole* is Elevated in { *South* / *North* } *Decliners.*

In

In North Recliners.

Note 1. The Fourth Tangent is to be compared with the *Complement* of the *Old Latitude*, and their *Difference* is the *NEW LATITUDE.*
Note 2. If the Fourth Tangent prove to be *Equal* to your *Old Latitude*, the Declining Reclining Plain will be an *EQUINOCTIAL PLAIN, DECLINING.*

II. *To find the* New Declination.

As the *Radius*, 90 deg.	10.000000
To the Co-sine of the Reclination 36 deg.	9.769213
So is the Sine of the Old Declination 24 deg. 20 min.	9.614944
To the Sine of 14 deg. 1 min.	x9.384162

Which 14 deg. 1 min. is the *New Declination*

III. *To find the Angle made between the Meridian and the Horizon.*

As the *Radius*, 90 deg.	10.000000
To the Tangent of the Old Declination 24 deg. 20 min.	9.655347
So is the Sine of the Reclination 54 deg.	9.907957
To the Tangent of 20 deg. 6 min.	x9.563304

Whose Complement 60 deg. 54 min. is the *Angle that the Meridian must make with the Horizontal Line of the Reclining Plain.*

For the manner how the *Meridian* is to be drawn, whether to *ascend above*, or to *descend below* the *Horizontal Line*, the Fourth *Section* of the Fourth *Chapter* hereof, will direct.

CHAP. VII.

Another Way, by the Scale of Sines only, To describe Hour-Lines upon Direct and Declining Plains.

I. *For Horizontal North or South Plains either Upright or Reclining.*

WITH the *Radius* of your *Scale* of *Sines* upon A as a *Center*, describe the *Quadrant* A B C. Also take out of the same Scale the respective Sines of the Equinoctial hour distances, as of 15,30,45,60, and 75, and prick them down upon the Semidiameter of the Quadrant A C from A at the points 15,30,45,60 and 75, and through them draw right Lines parallel to the Side A B of the Quadrant, as the Lines 15 *a*, 30 *b*, 45 *c*, 60 *d*, and 75 *e*, which will divide the Quadrant's Limb B C into six equal parts, for B *a*, *a b*, *b c*, *c d*, *d e* and *e* C, are each of them 15 deg. of your Scale of Chords:—Also take the Sine of the Latitude (suppose 40 deg.) out of the Scale of Sines, and set them from A to D, and drawing the Line D E parallel to A B, and the Line A E for the Axis or Stile of the Dial. *Figure* VII.

Ff   This

This done, take with your Compaſſes the leaſt Diſtance

From	15	*to the* Axis A E, *and ſet it from*	75 *to* 11	*upon the Line*	75	*e*
	30		60 *to* 10		60	*d*
	45		45 *to* 9		45	*c*
	60		30 *to* 8		30	*b*
	75		15 *to* 7		15	*a*

Make A 6 equal to the Line D E, or ſet the Sine of the Latitude (40 deg.) from A to 6.—Now if with an even hand a Line be drawn thro' the ſeveral Points C, 11,10,9,8,7,6, it ſhall be one quarter of an *Ellipſis:* And right Lines drawn thro' thoſe Points from the Center A,ſhall be the true Hour-lines of an Horizontal Dial for the Latitude of 40 deg. or of a South or North Dial in the Latitude of 50 deg. or of any Reclining or Inclining Plain in any Latitude where the Height of the Stile above the Plain is found to be equal to 40 deg.

II. *For Upright Declining Plains.*

If an Upright Plain in the Latitude of 40 deg. ſhould decline from the South Eaſtward 14 deg. by ſeveral ways before taught (in the 1*ſt*. 2*d*, 3*d*, Tractate) the Height of the Pole or Stile above ſuch a Plain would be found to be 48 deg. 1 min.—The Diſtance of the Subſtile from the Meridian 13 deg. 42 min.— And the Plain's Difference of Longitude 13 deg.

The Plain's difference of Longitude being known make a Table of the Equinoctial diſtances as is before taught in the 12th and 13th Chapters of the Firſt Tractate, as is here done in this Table. You may proceed to the deſcription of the Dial in this manner.

Hours		*Equinoctial Diſtances.* deg.	min.
6	6	82	0
7	5	57	0
8	4	42	0
9	3	27	0
10	2	12	0
Subſtile			
11	1	3	0
12	12	18	0
1	11	33	0
2	10	48	0
3	9	63	0
4	8	78	0

Figure VIII. Firſt, Draw a right Line O 12 for the Meridian and Hour-line of 12; and upon O with the *Radius* of your Scale of Chords deſcribe a Quadrant of a Circle and upon it from 12 to P, ſet 13 deg. 42 min. the Diſtance of the Subſtile from the Meridian, and draw the Line O P for the Stile.

Secondly, Take 43 deg. 1 min. and ſet them from P to S, and draw O S for the Stile.

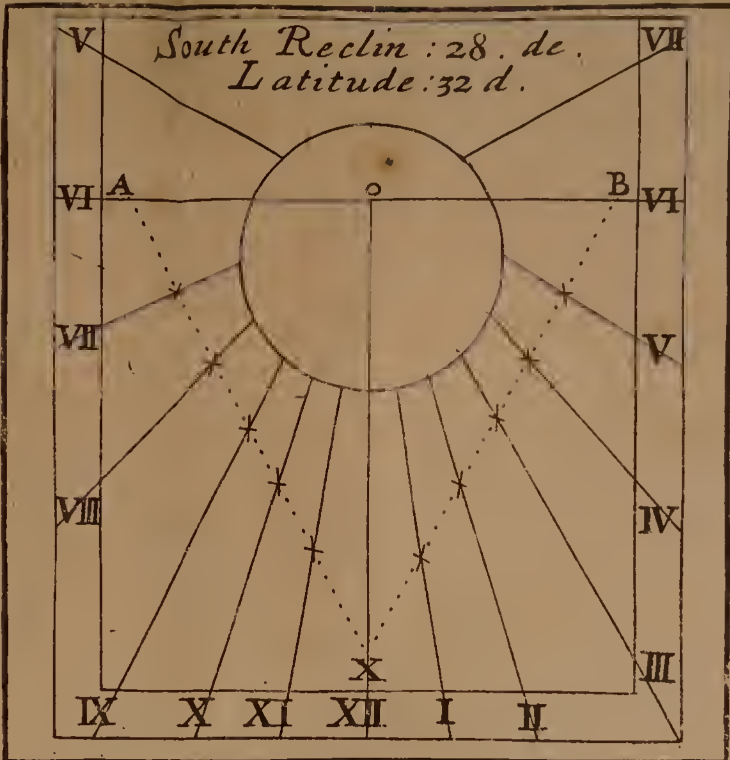
Thirdly, out of the former Table, take the Reſpective Sines of 82,57,42,27 and 12, and ſet them from O to the ſeveral Points 82,57,42,27 and 12 upon the Subſtile, and through them on the left hand Side of O P, draw Lines Perpendicular to the Subſtile: as the Lines 82 *a*, 57 *b*, 42 *c*, 27 *d* and 12 *e*——Alſo, ſet the Sine of 3, 18, 33, 48, 63 and 78 upon the Subſtile O P, and thro' them draw Lines perpendicular to O P towards the Right-hand.

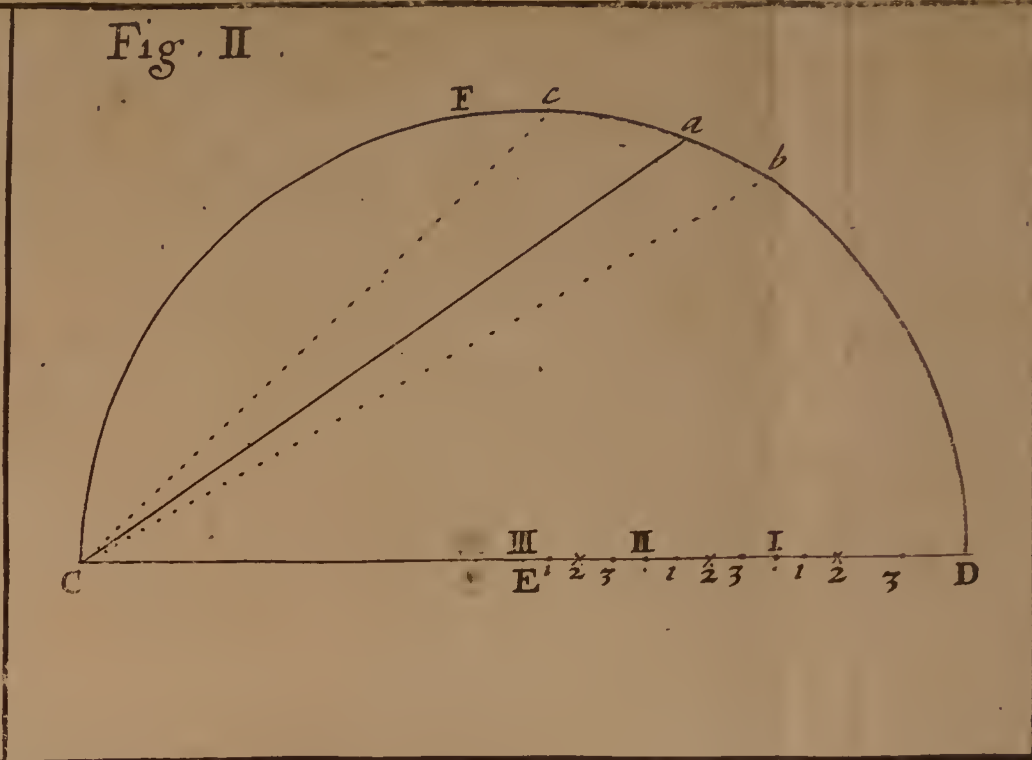
Fourthly, Take in your Compaſſes the leaſt diſtance

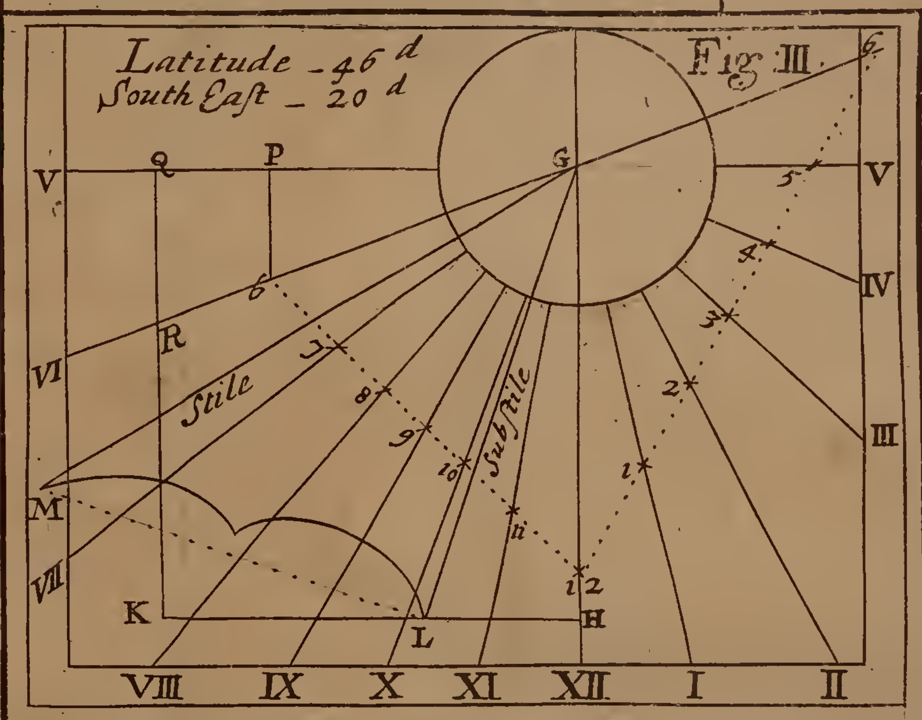
From	82	*to the Subſtile* S O, *and ſet it from*	12 *to* 6	*upon the Sine*	12	*e*
	57		27 *to* 7		27	*d*
	42		42 *to* 8		42	*c*
	27		57 *to* 9		57	*b*
	12		82 *to* 10		82	*a*

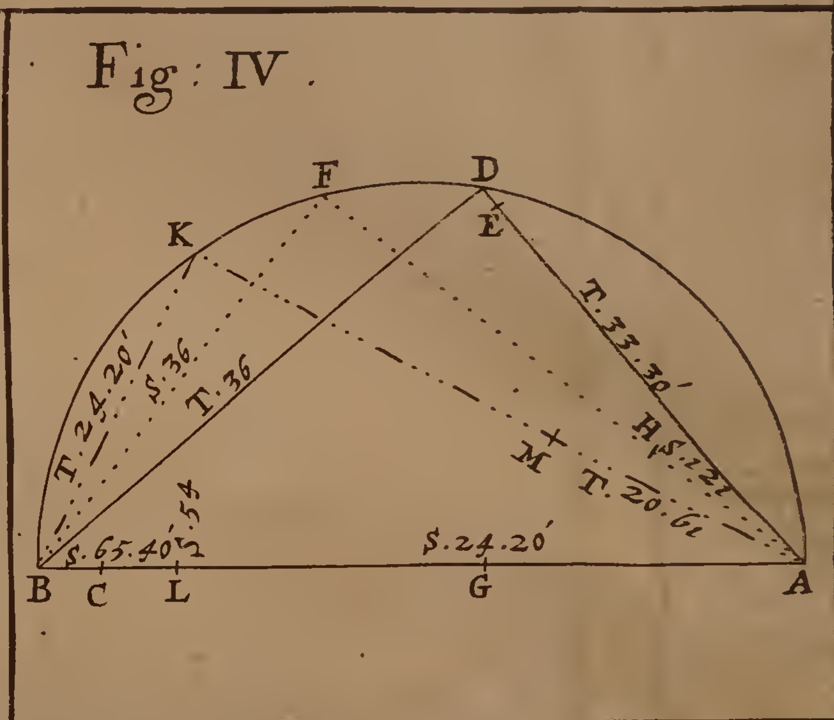
So ſhall the ſeveral Points 6, 7, 8, 9, 10 and P conſtitute almoſt one quarter of an *Ellipſis*, and Lines drawn from O thro' every of them ſhall be the true Hour-lines for the Plain on the Weſt Side of the Subſtile: For thoſe on the Eaſt Side they muſt be found by taking the leaſt Diſtances from the Points 78, 63, 48, 33, 18, and 3 to the Subſtile, and ſetting them upon their contrary parallel Lines; ſo ſhall Lines drawn from O thro' each of them be the Afternoon-Lines on the Eaſt Side of the Plain.

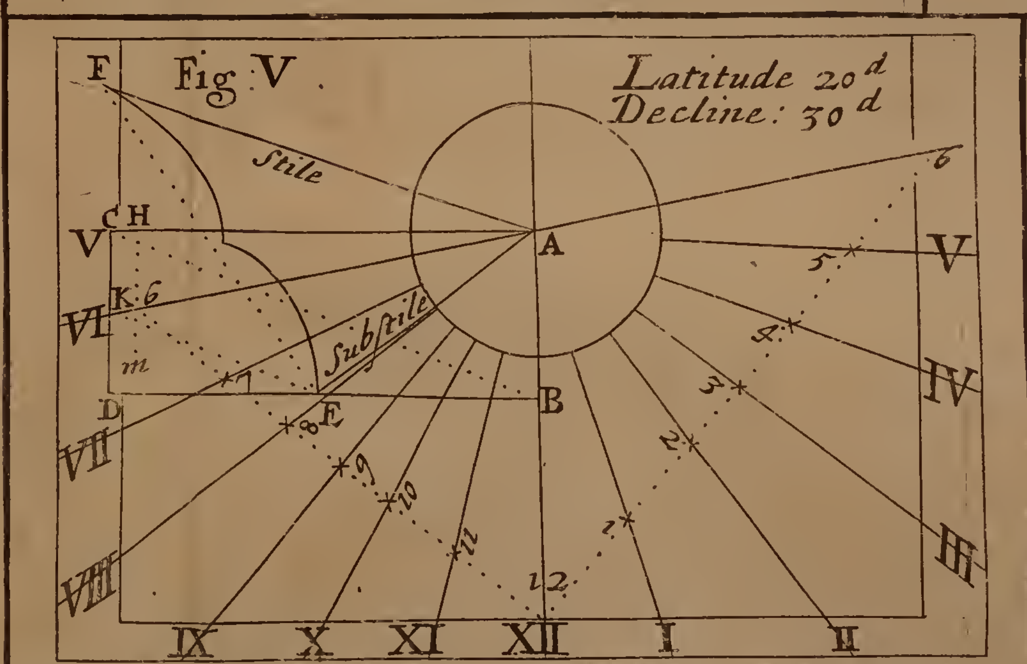
The End of the Third TRACTATE.

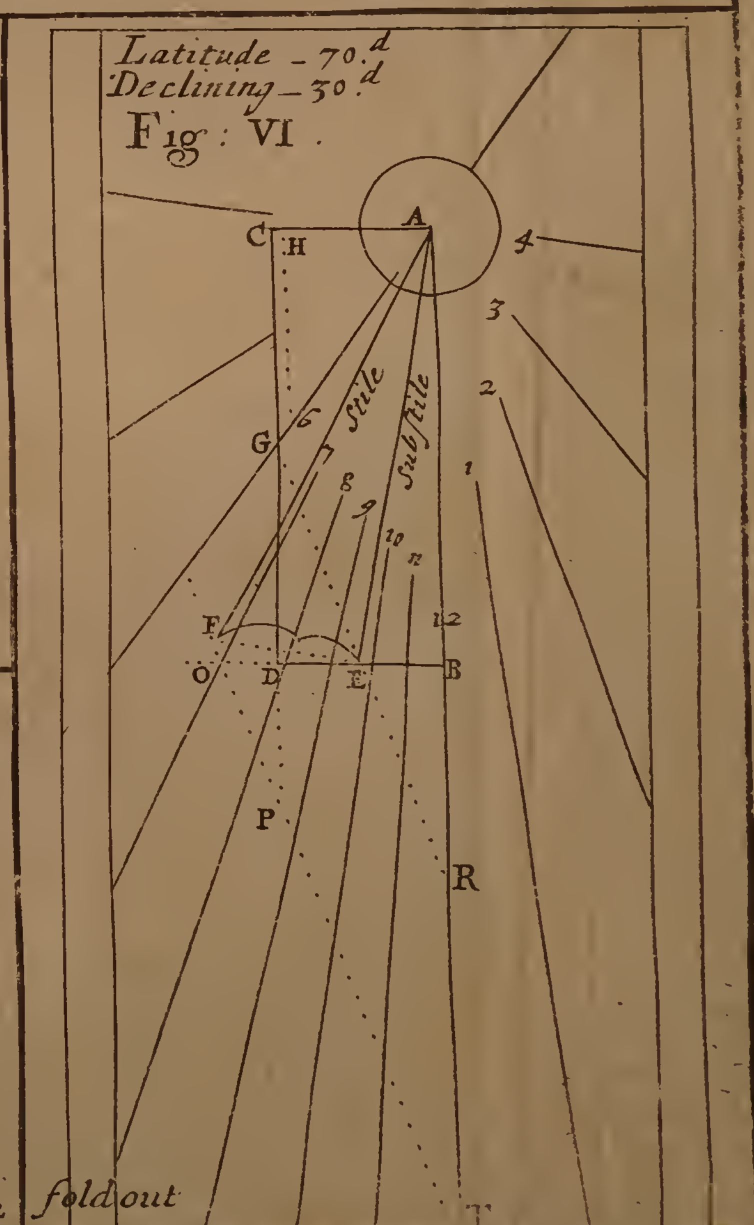


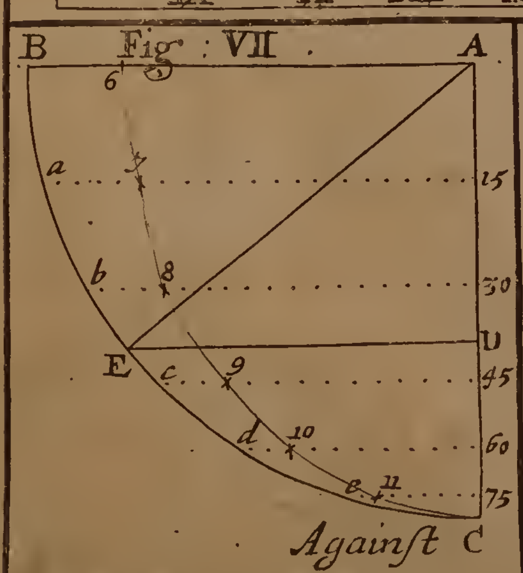


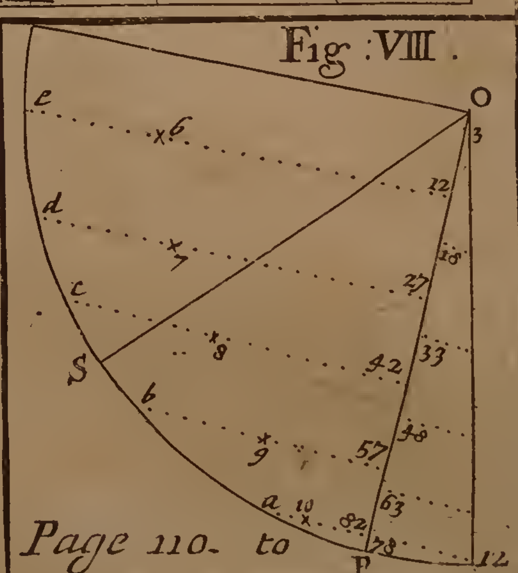












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OF THE FURNITURE With which SUN-DIALS May be Beautified;

AND

How to Inscribe such Furniture upon all Sorts of DIAL-PLAINS; Several ways.

The Fourth TRACTATE.

PROEME.

AS *Lines* may be described upon all sorts of *Plains*, which by the shadow of a *Stile* or *Axis* will shew upon the *Dial-Plain* the true *Hour* of the Day: So also upon such *Plains* may such other *Lines* be described that have relation to the *Sun's Course*, which by the Shadow of an *Apex* (or *Point* in that *Axis*) shall trace out, and discover upon the *Plain*, many useful and necessary *Astronomical* Conclusions —— As to shew the *Time* of the *Year* —— The *Rising* and *Setting* of the *Sun* —— The *Length* of the *Day* and *Night* —— The *Azimuth*, or *Point* of the *Mariner's Compass* upon which the Sun at any time of the Day is —— The *Almicanthar*, or *Circle* of the Sun's *Altitude*; whereby the proportion that any *Object* bears to its *Shadow* is discovered —— The *Babylonish*, *Italian* and *Jewish* (or Unequal) *hours* —— The *Sign* of the *Zodiack* in the *Meridian*, with those *Ascending* and *Descending* —— And the *Circles* of *Position*, discovering in which of the *Twelve Celestial Houses* the *Sun* at any time of the Day is, *&c.*

CHAP. I.

Of the Habitudes, *or* Affections, *that such* Great *and* Small Circles *of the* Sphere, *which may be Projected upon* Dial-Plains, *have to all such* Plains, *as they may be described upon.*

BEfore I proceed to shew the manner of inscribing these *Circles* of the *Sphere* upon *Dial-Plains*, let me give you a short account of their *Affections*, which I Reduce to these following Heads.

I. *All* Great Circles *of the* Sphere, (*such are all* Meridians *or* Hour-Circles, *all* Azimuths *or* Vertical Circles, *all* Circles *of* Position, *&c.*) *being Projected upon any* Dial-Plains, *do become thereon* Streight Lines. *And*,

II. (1.) *If the* Plains *on which such* Great Circles *are Projected, do lie, or stand,* Parallel, *to those* Great Circles *in the Heavens, then are those* Streight Lines *all* Parallel *one to the other. But*, (2.) *If the* Plain *upon which they are Projected, lie, or stand,* Perpendicular *to the corresponding Circles in the Heavens, then the streight Lines so projected on the* Dial-Plain, *shall all* meet in a Center at Equal Angles; *And*, (3.) *If the* Dial-Plain *upon which these* Great Circles *of the* Sphere *be Projected to lie at* Oblique Angles *to the same correspondent* Circles *in the* Heavens, *then shall all the* Projected Lines *representing those Circles in the Heavens*, meet in one Center upon the Plain, *but*, at Unequal Angles.

III. *All* Smaller Circles *of the* Sphere, (*such are all* Parallels *of the* Sun's Course *or* Declination, Almicanthars *or* Circles *of* Altitude) *being Projected upon any* Dial-Plain, *become* Conick Sections, viz. *either* Sections *of* Ellipses, Parabola's *or* Hyperbola's; *Except, those* smaller Circles *be projected upon such* Plains *as do lie* parallel *to those* smaller Circles *in the Heavens: And therefore*,

IV. *All* Parallels *of the* Sun's Course, *or* Declination (*which are smaller Circles*) *drawn upon a* Plain, *which lies* parallel *to the* Equinoctial *in the* Heavens, *which* Equinoctial *is that* Great Circle *of the* Sphere *to which these* smaller Circles *of the* Sun's Course *or* Declination *are* parallel; *those* Parallels *upon such a* Plain, *become* perfect Circles. *And*,

V. *All* Almicanthars *or* Parallels *of* Altitude, *being described upon a* Plain, *lying* parallel *to the Horizon, to which* Great Circle *all* Almicanthars *are* parallel, *those* Circles *of* Altitude *being described upon such a* Plain, *shall also become* perfect Circles, *by the same reason as the last beforegoing: For, the* Almicanthars *have the same Affection or Habitude to the* Horizon, *as the* Parallels *of* Declination *have to the* Equinoctial.

VI. *All* Dial-Plains *in any* Latitude, *and howsoever situate in that* Latitude, *whether they be* Direct, Declining, Reclining, Inclining, *or do both* Decline *and* Recline; *are in some one part of the World or other*, Horizontal Plains, *And look what* Altitude *or* Elevation *the* Stile *of any such Oblique* Dial *hath in any* Latitude, *in that* Latitude *will that* Plain *be an* Horizontal Plain, *but under another* Meridian.

VII. *When the* Hour-Lines *proper to any* Dial-Plain *be drawn thereupon with their* Halves *and* Quarters. *If upon the same* Plain (*afterwards*) *you draw an* Horizontal Dial (*in occult or obscure Lines*) *proper to that* Latitude *in which the* Plain *will be* Horizontal, *and find upon those* Occult Horizontal Hour-Lines, *points through with such* Hours, Azimuths, Parallels *of the* Sun's Course *or* Declination, Almicanthars, &c. *shall pass, and draw the* Section (*whatever it happens to be*) *through those points, and afterwards expunge the* Horizontal Hour-Lines, *the* Parallels, *so drawn, shall be the true* Parallels *of the* Sun's Course *upon the other* Plain, *whether it be* Direct, Declining, Reclining, *or* both.

VIII. *The whole* Stile *or* Axis *of the* Dial *which shews the* common Hour *of the* Day, *doth not shew the* Parallels *of the* Sun's Course, *&c. but the* Shadow *of some* one Point *in that* Stile *or* Axis; *the* Shadow *whereof, as it creepeth along those* Lines *or* Sections, *will shew you what the* Time, *or* Quantity *is.*

Having

Having premiſed theſe few *Affections:* I ſhall ſhew you firſt *Geometrically*, and then *Arithmetically* and *Inſtrumentally*, or by Tables ready calculated, how to find *Points* upon any *Plain*, through which ſuch *Lines*, *Circles*, or *Conick Sections* are to paſs; and the Points being found, I ſhall diſcover unto you whether they be *Streight Lines*, *Arches* of *Circles*, or other *Sections Elliptical*, *Parabolical* or *Hyperbolical*.

Now (becauſe the Sun in his Courſe moveth Continually between the two *Tropicks*, and never exceedeth thoſe Limits) all Aſtronomical Concluſions that are drawn or deſcribed upon any *Dial-Plain*, are limited between theſe two *Tropical Circles*, or (at leaſt,) between the *Equinoctial* and one of them, or the Horizon: And therefore it will be requiſite to ſhew, firſt how theſe *Circles* (namely the *Equinoctial*, and the two *Tropicks*) and the Horizon may be deſcribed upon all ſorts of *Plains*, they being the Bounds and Confines of all other *Circles* whether of the Sun's entrance into the 12 *Signs*; or *Diurnal Arches:* or of any other intermediate *Parallels* of the *Sun's Declination:* And to ſhew how they may be inſcribed upon all Plains, ſhall be the work of this following Chapter.

CHAP. II.

How to deſcribe the Equinoctial, *the two* Tropicks, *and other* Circles *or* Parallels *of* Declination, *together with the* Horizon, *upon all ſorts of* Plains.

These *Circles* (as I have ſaid already) become various Sections according as the *Plains* upon which they are projected are ſituate in reſpect to thoſe *Circles* in the Heavens: And therefore I will begin to ſhew their Inſcription upon ſuch Plains,

First, As lie *Perpendicular*
Secondly, As lie *Parallel* } to the *Axis* of the *World*.
Thirdly, As lie *Obliquely*

SECT. I. *Upon ſuch* Plains *as are* Perpendicular *to the* Axis *of the* World: *As, upon the Direct* Polar Plain.

A *Polar Plain* is ſuch a Plain as cutteth the *Axis* of the World at right Angles, as is deſcribed in the 16 *Chapter* of the Firſt *Tractate*. And is no other than a Circle divided into 24 equal parts: And this Plain cutting the *Axis* of the World at right Angles is perpendicular thereunto, and therefore muſt needs lie in (or parallel to) the very *Plain* of the *Epuinoctial Circle* in the Heavens: And therefore the *Equinoctial* it ſelf, and all other *Parallels* of *Declination* being deſcribed upon this *Plain*, will be perfect *Circles:* The *Stile* of this *Dial* (as in the making of it is ſhewed) may be a ſtreight *Pin* or *Wyre* perpendicularly erected upon the Plain, and iſſuing from the Center, where all the *Hour-lines* meet with equal Angles: The length of this *Stile* or *Wyre* is arbitrary, in reſpect of the *Hour-lines:* but the *Apex* or Top thereof, which muſt give ſhadow to the *Parallels* of *Declination* (or other *Aſtronomical Circles*

 deſcribed

described upon this Plain) will require a Proportionable limitation between the length of the *Stile*, and the largeness of the *Plain*: and therefore I will shew,

I. *How to proportion the* Stile *to the* Plain.

Upon this *Plain*, the *Equinoctial Circle* it self cannot be described, which is evident, for the Sun being in this Circle, it will cast the Shadow of the *Apex* of the *Stile* (be it made never so short) to an infinite extension, and for some few days before and after the two *Equinoxes*, the *Furniture* inscribed upon these *Dials* will be of little use; And the *Reclining* or upper face of this Dial the Sun will shine upon from the Tenth of *March* to the Twelfth of *September*, and from thence to the Tenth of *March* again, the *Inclining* or under face thereof will be wholly in use.

Consider therefore what *Parallels* of *Declination* you intend to describe upon your Plain; And let the outermost Verge or Circle of your Plain represent that *Parallel* which hath least *Declination* from the *Equinoctial* Circle. *Figure* I. In this *Example*, I have made choice (for a Reason which will hereafter appear) of these Parallels, *viz.* of 11 deg. 37 min. of 16 deg. 55 min. of 21 deg. 40 min. and of 23 deg. 31 min. which is the *Declination* that the Sun hath when he is in either *Tropick*.

Let E S W N represent a *Polar Plain*, cross it with the two Diameters S N for the *Meridian*, and Hour-line of XII, and E W for the Hour-line of VI, crossing each other at right Angles in A. So is A the *Center* of the *Dial*, and the outer Circle thereof the *Parallel* of the Sun's Course when he hath 11 deg. 37 min. of *Declination*.

Now to Proportion the *Stile* to the *Plain*, upon a piece of fine Past-board or other like matter, draw a Line at length as B C, and out of your Dial-Plain take the distance from A to N, and set it upon this Line from C to D, and through D, draw the Line F D perpendicular to B C —— Then upon C, with 60 deg. of a *Scale* of *Chords* describe an obscure Arch of a Circle G H, and out of your Scale take 11 deg. 37 min. (the Declination of the remotest Circle E S W N from the Center) and set them from H to *a*, and draw the Line C *a* K, so shall K D be the length of the *Perpendicular Stile*: —— The *Stile* being thus proportioned to the *Plain*, the next thing necessary will be,

II. *To draw the* Horizontal Line *proper to this* Plain.

Many *Horizontal Lines* may be drawn upon any *Plain*, but the *Horizontal Line* Proper to this Plain, must be drawn upon the Plain, so, as to lie in the same Plain with the *Apex* or *Top* of the *Perpendicular Stile*, and to find the Point upon the *Meridian* S N, through which this Line must pass, do thus:

Upon the Point K, describe an obscure Arch of a Circle, and upon it set 51 deg. 52 min. the *Latitude of the Place* from D to L, and draw the Line K L, cutting the Line B C in M; So the distance D M taken in the Compasses, and set upon the Dial-Plain upon the Meridian from the Center A upwards to S in the *Reclining Plain*, (but downwards in the *Inclining Plain*) so a Line drawn through S, parallel to E W, as P S Q, it shall be the *Horizontal Line* proper for this *Plain*: and beyond this Line the *Tropicks* nor *Parallels* of *Declination*, or any other *Furniture* need to be extended. And now,

III. *To*

III. *To draw the* Tropick *of* Cancer, *and the other* Parallels *of* Declination *upon the* Plain.

The other Parallels of Declination being 16 deg. 55 min. —— 21 deg. 40 min. —— 23 deg. 31. min. Set them upon the Arch G H of the *Trigon* from H to *b*, *c* and *d*; and draw the Lines C *b*, C *c*, C *d*.

This done, through the Point K, draw the Line K R Parallel to D C, and where that Line croſſeth the Lines of the *Trigon* drawn from C (as it doth at the Points K, *e*, *f* and *g*) through thoſe Points Lines being drawn Parallel to K D, as *e* 15, *f* 16, *g* ♋, ſhall give C D for the Semidiameter of the Circle P N Q upon the Plain —— The diſtance C 15, ſhall be the Semidiameter of the Circle 15. 15. 15 —— The diſtance C 16, ſhall be the Semidiameter of the Circle 16. 16. 16 —— And the diſtance C ♋, ſhall be the Semidiameter of the *Tropick* of ♋. ♋. ♋. —— With which *Semidiameters* if Circles be deſcribed upon the Center A, of the *Dial-Plain*, they ſhall be the true *Circles* for the *Sun's Courſe* when he hath ſuch *Declinations* as are inſerted into the *Trigon*. —— And in the ſame manner may you inſert what *Parallel* of *Declination* you pleaſe; Whether of the *Sun*'s Entrance into any *Sign* of the *Zodiack* —— Any Anniverſary or *Feſtival Day*, or what other *Remarkable Time* or *Day* you pleaſe, only having regard to what Declination the Sun hath at that time.

Note, That a Dial thus made, being elevated to the Complement of any *Latitude*, and moved above upon a *Semicircle* as a *Declinatory*, till the Shadow of the *Apex* of the *Stile* do cut the *Parallel* of *Declination* for the Day, you ſhall, at one view, have the Hour of the Day, a *Meridian Line*, and the *Declination* of a *Plain*; without taking the Sun's *Altitude*, or finding his *Azimuth*.

SECT. II. *Upon ſuch* Plains *as are* Parallel *to the* Axis *of the* World; *As upon the* Eaſt, Weſt *and* Polar Plains.

HOw to make an *Eaſt* or *Weſt* Dial you are taught before, therefore let the *Square* A B C D be a Plain, on which there is an Eaſt Dial drawn, the height of the Stile being equal to the diſtance between the hours of 9 and 6, noted there with the Letters E G, and let it be required to draw upon the ſame Plain the *Equinoctial* and the two *Tropicks*. Now the *Equinoctial* being a *Great Circle* of the *Sphere*, it is therefore a *Streight Line*, and is repreſented in the Dial by the Line H S. The *Hour-lines* and the *Equinoctial* being thus drawn, we may proceed to the reſt of the Work in manner following. *Figure* II.

But firſt, it will be neceſſary to draw the *Horizontal Line* proper for the *Plain*: which is done in this manner; for in all *Upright Plains*, whether *Direct* or *Declining*, this is for drawing the *Horizontal Line*,

A General Rule.

In all *Upright Plains*, the *Horizontal Line* muſt be drawn through the *Foot* of the *Perpendicular Stile*, and alſo through the interſection of the *Equinoctial* Circle with the *Hour-line* of *Six*: In theſe *Eaſt* or *Weſt* Dials theſe two Points are co-incident, and is here the Point E, wherefore through the Point E, draw the Line M E N parallel to the *Horizon*,

Horizon, or making the Angle M E G equal to the Latitude of the Place 51 deg. 32 min. the Line M E N ſo drawn ſhall be the proper *Horizontal Line* for this *Plain.*

The *Equinoctial Circle* E S and the *Horizontal Line* M E N, being drawn upon your *Plain*; proceed as followeth.

Figure III. Upon a piece of fine Paſt-board, or other convenient matter, draw a Line as O R, and upon O, as a Center, deſcribe the Arch of a Circle R S, and becauſe the Declination of the Tropick of *Cancer* or *Capricorn* is 23 deg. 31 min. diſtant from the Equinoctial, on either Side thereof, therefore on the Arch R S ſet 23 deg. 31 min. from R to S, and draw the Line O S, then ſhall the Line O R repreſent the *Equinoctial*, and the other Line O S either of the *Tropicks*, and this Triangular Figure O R S, we ſhall hereafter call the *Trigon.*

Having fitted your *Trigon*, you muſt have recourſe to your *Dial*, and from thence with your Compaſſes you muſt firſt take out the diſtance E G (equal to the height of the Stile of the ſame Dial) and prick it down in the *Trigon* from O to P, and draw the Line P 6 perpendicular to O R.

Secondly, Going to your Plain again, take the diſtance from G (the Top of the Stile) to 7 the *Equinoctial* of your Plain; and place that diſtance in the *Trigon* from O to *q*, and draw the Line *q* 7, perpendicular to O R. Thirdly, take out of your Plain the diſtance G 8, and prick it down in your *Trigon* from O to *r*, and draw the Line *r* 8, perpendicular to O R. Fourthly, take out of your Plain the diſtance G 9, and prick it down in your *Trigon* from O to *s*, and draw *s* 9 perpendicular to O R. Fifthly, take out of your Plain the diſtance G 10; and prick it down in your *Trigon* from O to *t*, and draw *t* 10 perpendicular to O R. Laſtly, take the diſtance G 11, and prick it down in your *Trigon* from O to *v*, and draw *v* 11 perpendicular to O R, as is done in Figure III.

Theſe diſtances being, all of them, taken out of your *Plain*, and placed on your *Trigon*, it reſteth now to ſhew you how they muſt be again transferred from the *Trigon* to the *Plain.* Therefore, to find upon the Hour-lines of your Dial, the Points through which the *Tropick* of *Cancer* muſt paſs, you have no more to do but thus. Firſt, out of your *Trigon*, take the diſtance P 6, and ſet that ſame diſtance upon your Plain from E to *c*, upon the Hour-line of Six. Secondly, take out of your *Trigon* the diſtance *q* 7, and place that diſtance upon the Plain from V to *b*, and from VII to *d*: upon the Hour-lines of 5 and 7. Thirdly, take out of your *Trigon* the diſtance *r* 8, and ſet that diſtance on your Plain from IV to *a*, and from VII to *e* upon the Hour-lines of 4 and 8. Fourthly, take out of your *Trigon* the diſtance *s* 9, and ſet it on your Plain from IX to *f*. Fifthly, take from your *Trigon* the diſtance *t* 10, and ſet it on your Plain from X to *g*. Laſtly, take out of your *Trigon* the diſtance *v* 11, and ſet it on your Plain from XI to *h*.

Theſe Points *a b c d e f g h*, being found upon the ſeveral and reſpective Hour-lines, ſhall be the Points through which the *Tropick* of *Cancer*, ſhall paſs, therefore draw the Line *a b c d e f g h*, with an even hand that it make no Angles and that ſhall be the *Tropick* of *Cancer*; ſo that when the Sun is in *Cancer*, (which is about the 11 of *June*) the *Apex* or Top of the Shadow of the Stile of your Dial will run directly along that Line *a b c d e f g h*, and when the *Sun* is in the *Equinoctial*, that is, in the beginning of *Aries* or *Libra*, (which is on the 10 of *March*, or the 12 of *September*) the Top of the Shadow of the Stile will run along the *Equinoctial Line* E S.

The

The *Tropick* of *Cancer* being drawn, I will now ſhew you how to draw the *Tropick* of *Capricorn*, which differeth nothing from that of *Cancer*, becauſe they have both of them like *Declination* from the *Equinoctial*, therefore the diſtance VIII *k* being made equal to the diſtance VIII *e*, and the diſtance IX *l* equal to IX *f*; and the diſtance X *m* equal to X *g*, you ſhall have the Points *k l m* and *n* upon the hours of 8, 9, 10 and 11, through which Points *k l m n* draw the Line *k l m n*, *&c.* which Line ſhall repreſent the *Tropick* of *Capricorn*, along which Line the Top of the Shadow of the Stile ſhall run about the 11th of *December*, when the Sun is in *Capricorn*.

Having thus plainly ſhewn you how to inſert the *Equinoctial* and *Tropicks* into your Plain, I will now give you one Rule by which you may put on any other intermediate *Parallels* of the *Sun's Courſe*, differing nothing at all from the directions formerly given you to inſert the *Tropicks*.

Conſider therefore what *Parallels* you would put on your Plain, and find what Declination the Sun hath when he is in ſuch a Parallel, and accordingly inſert thoſe degrees of *Declination* into your *Trigon*, as before you did the *Tropicks*.

Example, Let it be required to put upon your Plain, the *Parallels* of the Sun's Courſe at his Entrance into the 12 *Signs* of the *Zodiack*: You muſt, firſt, find what Declination the Sun hath when he enters any of thoſe Signs, which this little Table doth plainly ſhew: For at the Sun's Entrance into *Aries* or *Libra*, it hath no degrees of Declination. And when he enters into *Cancer* or *Capricorn* he hath 23 deg. 31 min. of Declination; And when he enters into *Taurus*, *Virgo*, *Scorpio*, or *Piſces*, his *Declination* is 11 deg. 30 min. and when he is in the beginning of *Gemini*, *Leo*, *Sagittarius* or *Aquarius*, his *Declination* is 20 deg. 12 min.

A Table ſhewing what Declination the Sun hath at his Entrance into the Twelve Signs.

			D	M			
North Decli.	*Aries*		00	00	*Libra*		South Decli.
	Taurus	*Virgo*	11	30	*Scorpio*	*Piſces*	
	Gemini	*Leo*	20	12	*Sagittarius*	*Aquarius*	
	Cancer		23	31	*Capricorn*		

Therefore take 11 deg. 30 min. in your Compaſſes, and place it in your *Trigon* from R unto V, and draw the Line O V, which ſhall repreſent the Parallel of *Taurus*, *Virgo*, *Scorpio* and *Piſces*. Alſo take 20 deg. 12 min. in your Compaſſes and place it in your *Trigon* from R unto X, and draw O X, which ſhall repreſent the parallel of *Gemini*, *Leo*, *Sagittarius* and *Aquarius*.

Theſe Parallels being placed in your *Trigon* according to their true *Declination* from the *Equinoctial*, they are to be transferred into your Dial-Plain in all reſpects as the *Tropicks* were, by taking out of your *Trigon* the diſtances from the Line O R, to the ſeveral Points where the hours croſs the Parallel, and place the ſame diſtances upon your Plain from the *Equinoctial* upon the reſpective Hour-lines, from which they were taken out of the *Trigon*, and through theſe Points draw with an even hand the Lines on your Plain, which

ſhall be the true *Parallels* of the Sun's Courſe at his Entrance into all the 12 Signs of the Zodiack, to which you may ſet the Characters of the Signs, as you ſee done in Figure II.

¶ And here note, That if you draw upon your Plain the halves and quarters of hours, and put them into your *Trigon* and transfer them to your Plain again, you ſhall then have more points, through which your *Parallels* muſt paſs, which will much help you in the drawing thereof, (eſpecially in large Plains) for there is no better way to draw theſe kind of lines, but by finding a great number of points, and ſo draw them with an even hand, ſo that they make no Angles.

¶ Note alſo, That whatſoever is here ſpoken of the *East* and *West* Dials, the ſame in all reſpects is to be obſerved in putting on the Parallels of the Sun's Courſe in all Plains that lie parallel to the *Axis* of the World, as all Equinoctial Plains whether *Direct* or *Declining*, do: An Example of ſuch a Plain you have in Figure IV.

Figure IV.

In all theſe Plains, I mean *East*, *West*, and *Equinoctial*, the Stile were beſt to be made of a ſtreight piece of Wyer, equal in length to the Line E G, fixed in the Point E, ſtanding perpendicular unto the Plain, the end thereof at G being filed very fine and ſharp, proportionable to the greatneſs of the Plain, for all theſe *Aſtronomical Concluſions* are ſhewed (not by the ſhadow of the whole length of the Stile, but) by the very *Apex* or Top thereof, and therefore the more care ought to be had in the forming and making of it.

Figure II.

¶ The Line M E N in the *East Dial* is called the *Horizontal Linē*, becauſe it lieth parallel to the *Horizon*, and by the meeting of the *Parallels* of the *Sun's Courſe* with this Line, the Riſing of the Sun may be nearly eſtimated; for there you ſee that the *Tropick* of *Cancer* cutteth this Line near the Point M, which is a little before the four-a-clock Hour-line, which ſheweth, that when the Sun is in the Tropick of *Cancer*, he riſeth ſomewhat before four in the Morning, in like manner the Tropick of *Capricorn* cutteth the Horizontal Line ſomething after 8, at which time the Sun riſeth being in *Capricorn*, but this by the way; the farther uſe of this Line ſhall be ſhewed hereafter.

I have been the larger in the work of this *Section*, becauſe I intend to be more brief in thoſe which follow, and this being well and truly underſtood, thoſe which follow will need very few Precepts or Examples; Having thus finiſhed the *East* or *West* Plains, I will now ſhew you how to do the like in the *Vertical* or *Horizontal* Plains; As alſo in *South* or *North* Plains, that do not decline; which are the next in order: But firſt I ſhall give you the Sight of an Equinoctial Plain with its Furniture in Figure IV.

SECT. III. *Upon ſuch* Plains *as cut the* Axis *of the World at* Oblique Angles; *As upon the* Vertical *or* Horizontal, *the* North *and* South *Erect* Direct, *and the* North *and* South Reclining.

IN all theſe Plains the *Subſtilar* and the *Meridian* are all one, and the height of the Stile, in the *Vertical* or *Horizontal Dial* is always equal to the *Latitude* of the place, and you are to take notice, that whatſoever

ever is said of the full *North* and *South* Upright Plains, the same is to be understood of the *Vertical* or *Horizontal Plain*, the full *North* and *South Reclining* or *Inclining Plains*, all which in those *Latitudes*, whose Complement is equal to the height of the Stile, they are *Erect Direct North* or *South Plains*, and in those *Latitudes* which are equal to the *height of the Stile* above such *Reclining Plains*, they are *Horizontal Plains*. One *Example* therefore in one Plain will be sufficient for the rest. Therefore, in *Latitude* of 51 deg. 32 min. Let it be required to describe the Equinoctial, and the two Tropicks in a full South erect Plain.

Having drawn your *Dial* with the *hours*, *halves* and *quarters*, as also the Line C Q for the *Stile*, you must assume some point in the Meridian or Substilar Line through which to draw the *Equinoctial Circle*, which is a streight Line, and through what point soever you draw it, it must be *Parallel* to the Hour-line of *Six*, and consequently perpendicular to *Twelve*: but let it be such a point as the Equinoctial Line (with these conditions) may cross most of the *Hour-lines*. —— Let the point assumed be *a*, upon which point describe an Arch of a Circle, and make an Angle equal to the Latitude of the place, *viz.* 51 deg. 32 min. as the Angle L *a* S, drawing the Line *a* S, till it cut the Line of the Stile C Q in S, so shall the point S be the point in the Stile; for the *Nodus* or *Knot* which must give the *Shadow* to the *Tropicks* and other *Parallels* of *Declination*. For all these *Astronomical Conclusions* are not shewed by the Shadow of the whole length of the Stile or *Axis*, as the hour is, but by some point therein which representeth the Center of the Earth, which in the Dial following is the point S, and the *Triangular Stile* in that *Dial* is represented by the Triangle C S L, whereof G L is called the *Substilar*, C S the *Axis* of the Stile, and S L the *Perpendicular Stile*, the *Top* of which, *viz.* S, is the point we are in this place to respect, and thus is your Stile proportioned to your Plain. *Figure* V.

The *Dial* being drawn, and the Triangle C S L made equal to the *Cock* of the *Dial*, you must upon a piece of pastboard draw the *Triangle* O P R equal to the Stile in your Dial C S L, making R O equal to C L the Substilar, P O equal to C S the *Axis* of the Stile, and P R equal to S L the length of the perpendicular Stile. *Figure* VI.

Then from the point P, raise a perpendicular as P B, representing the *Equinoctial*, and on P as a Center, describe the Arch A B C, now because the Tropicks of *Cancer* and *Capricorn* do decline 23 deg. 31 min. from the *Equinoctial*, therefore take 23 deg. 31 min. from your *Scale of Chords*, and set it off upon the Arch A B C from B to A, and from B to C, and draw the Lines P A and P C representing the two Tropicks of *Cancer* and *Capricorn*. This done, extend the Line of the *Substilar* R O (which in *North* or *South* erect direct Plains, and also in the Vertical or Horizontal Plain I told you, was always the same with the Twelve-a-clock Line) from O to 12, cutting the *Equinoctial Line* P B in the point *a*, then with your Compasses take the distance O *a* out of the *Trigon*, and place it in your Plain from the Center C unto *a*, and draw the Line ♈ *a* ♎ perpendicular to the Substile or Line of 12; which Equinoctial being drawn: First, take out of your Plain the distance C *b*, and place that distance in your *Trigon* from O unto *b*, and draw the Line O *b* 1; representing the hour of 1 or 11 in your Dial: Secondly, take out of your Plain the distance C *c*, and place that in your *Trigon* from O unto *c*, and draw the Line O *c* 2, representing the Hour-lines of 2 or 10. Thirdly, take out of your Plain the distance C *d*, and place it in your *Trigon* from O unto *d*, and draw the Line O *d* 3, for the hours of 9 and 3. Fourthly, from your Plain take the

distance

diſtance C *e*, which ſet in your *Trigon* from O unto *e*, and draw the Line O *e* 4 repreſenting the hours of 4 and 8. And thus muſt you do with the reſt of the hours in your Plain if occaſion require.

Theſe Lines O *a*, O *b*, O *c*, O *d*, and O *e*, in your *Trigon*, being extended, do cut the *Tropick* of *Cancer* P A in the points 12, 1, 2, and 3, and the Line P C repreſenting the *Tropick* of *Capricorn* in the point, 12, 11, 10, 9 and 8; therefore out of your *Trigon* take the diſtances O 12, O 1, O 2, O 3, O 4, and ſet them upon their correſpondent *Hour-lines* of your Plain, from the Center C unto *g h i k* and *l*, ſo ſhall the points *g h i k* and *l* be the points upon the Hour-lines, through which the *Tropick* of *Cancer* muſt paſs, and is therefore noted with the Character of *Cancer* ♋ at both ends.

¶ Now before you draw the Tropick of *Capricorn*, it is neceſſary to draw the Horizontal Line of your Plain A B, which Line in all Upright Plains, not declining, muſt be drawn through the point L, the foot of the *Perpendicular* Stile, and perpendicular to the *Meridian* or Line of 12: And in all Plains whatſoever, this Line muſt be drawn through the Interſection of the *Equinoctial* with the hour of Six. This Line ought firſt to be drawn, becauſe it is very improper to extend the *Tropicks* or other *Parallels* of *Declination*, above the *Horizontal Line*, becauſe at what hour any Parallel of *Declination* cutteth this Line, on either ſide of the *Meridian*, at that time doth the Sun *Riſe* or *Set*, as was inſtanced in the laſt.

Now the Tropick of *Capricorn* muſt be put upon your Plain in the ſame manner as that of *Cancer*, by taking out of your *Trigon* the diſtance from O, to the points 11, 10, 9 and 8, where the ſeveral Hour-lines *a b c d e* do cut the Tropick of *Capricorn* P C, and place them on your Plain from the Center C upon the reſpective Hour-lines, and through thoſe points ſo found, draw the curved Line ♑ ♑, repreſenting the *Tropick* of *Capricorn*.

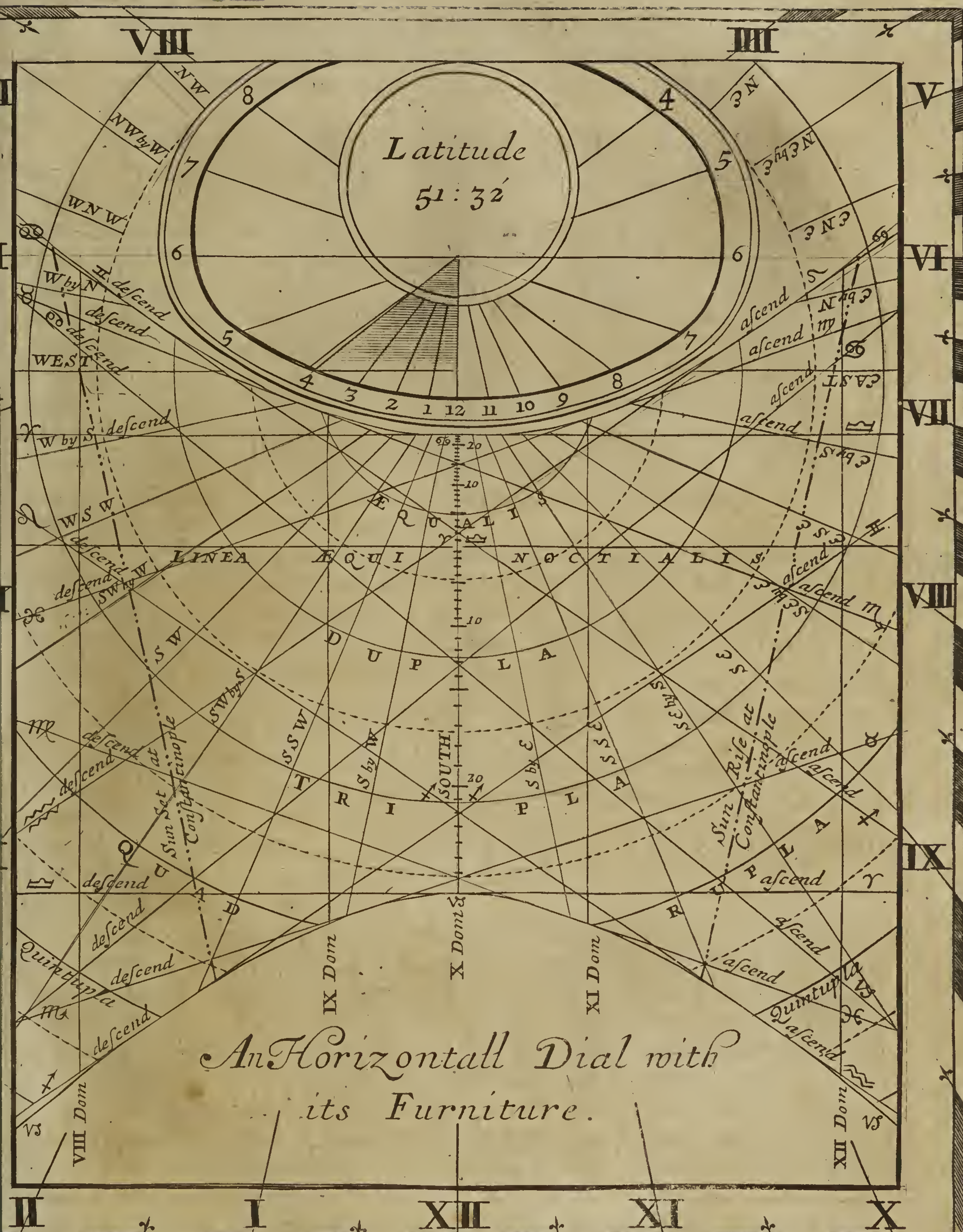
¶ And in the ſame manner may the Parallels of the other Signs be drawn upon your Plain, by placing them into your *Trigon*, according to their *Declinations*, and afterwards transfer them into your Plain, as you ſee in Figure V.

The Rules that have been here given for the deſcribing of the Parallels of the Signs in this Erect Direct Plain, is Univerſal in all Plains, obſerving this one Exception; that whereas in all *Erect Direct Plains* the *Equinoctial* is drawn perpendicular to the *Meridian* or Line of 12, ſo in all other Plains whatſoever, the *Equinoctial* muſt be drawn *Perpendicular* to the *Subſtile*, and the Horizontal Line through the Interſection of the Hour-line of Six with the Equinoctial, and then the Work will be the ſame in all reſpects, as may appear more largely in this next *Section*.

SECT. IV. *In* North *or* South *Erect* Declining; *In* Eaſt *or* Weſt *Direct* Reclining: *Or on* North *and* South Declining *and* Reclining *Plains*.

THE *Caution* preceding is ſufficient for the performing of the Work of this *Section*, and therefore needeth no *Example*: For every one of theſe laſt mentioned Plains is an *Horizontal Plain* to that place in the World which agrees in *Longitude* with the Plain's *difference of Longitude*, and in *Latitude* equal to the height of the *Pole* or *Stile* above the *Plain*: I might here give you *Rules* and particular *Examples* in every one of theſe *Plains*, but I ſhall give you but one for all, and that ſhall be both *eaſie* and *general*, and come neareſt to the Work before taught in the laſt *Section*; And this way I prefer

for



'the end of ye Tenth Tractate against Page 120.

for theſe Reaſons,—— (1.) Becauſe you ſhall have Two *Dials* contrived in One.—— (2.) Becauſe the Work will be ſtill the ſame in all Plains, without any Variation. —— And (3.) Becauſe one half of the labour is ſaved, there being but 5 or 6 Hour-lines to work upon at the moſt, whereas in moſt of theſe ſorts of Dials here mention'd 9, 10, or 12 Hour-lines muſt ſometimes be made uſe of.

One Example I ſay ſhall ſerve for all, and let it be of a *South Plain Declining Eaſtward* 30 deg. and *Reclining* from the *Zenith* 55 deg. which is one of the Dials of the 17th *Chapter* of the Firſt *Tractate*; Whoſe *difference of Longitude* was there found to be 17 deg.38 min. And the *Stile's height* 19 deg.25 min.— This *Dial* being made, if you would deſcribe the *Equinoctial*, the *Tropicks* (and other Parallels of the Sun's Courſe) you muſt conſider that this Dial is an *Horizontal Dial* in that part of the World which lies *Eaſtward* from *London* 17 deg. and 38 min. And in the Latitude of 19 deg. 25 min. Wherefore, the true Hour-lines proper for this Plain, together with the Stile and Subſtile being drawn in their proper places; If you make the Subſtilar Line of this Dial to be the Twelve-a-clock Hour-line of an *Horizontal Dial* for the Latitude of 19 deg. 25 min. draw ſuch a Dial obſcurely upon this Dial-Plain (as the ſmall pricked Lines in Figure VII are :) then proceed to the drawing of the Equinoctial and Tropicks in this manner.

Let A be the Center of the *Dial*, and let the Diſtance of the *Meridian* and *Horizon*, the *Subſtile*, *Stile* and *Meridian* be ſet off upon the Semicircle E G F according to their true diſtances : as alſo the Hour-lines proper for the Plain by help of the *Table* in the forementioned 17th *Chapter* of *Tractate I.*—— Secondly, let an Horizontal Dial be made or calculated for the Latitude of 19 deg. 25 min. the *Stiles* height of the *Reclining Declining Plain*, which will be ſuch as this Table affordeth. Which diſtances being ſet upon the Semicircle E G F, from G the Subſtile both ways, they ſhall be the the *Horizontal Hour-lines*, and they will give the true hour of the Day in that Latitude wherein the *Plain* would be *Horizontal*.

Figure VII.

	hours		*deg.*	*min.*
For	12		00	00
	11	1	5	5
	10	2	10	52
	9	3	18	23
	8	4	29	56
	7	5	51	08
	6		90	00

This done, Aſſume any point in the *Subſtile* as D, through which to draw the *Equinoctial Line* at right Angles thereto; And upon the point D, make an Angle B D C equal to the Complement of the new *Latitude* 29 deg.25 min. *viz.* 70 deg. 35 min. drawing the Line D C, till it cut the *Axis* of the Stile A C, in C, ſo ſhall C be the *Nodus*, *Apex* or *Point* in the *Stile* which muſt give the *Shadow* to the *Tropicks* and other *Furniture* upon the *Dial*.

Again, Obſerve where the *Hour-line* of Six doth croſs the *Equinoctial Circle*, for through that point (always) muſt you draw the *Horizontal Line* of the *Plain* H O, and parallel to the *Horizontal* Baſe of the *Plain* E A F.

Figure VIII.

Now make a *Trigon*, wherein let C A be equal to the *Stile*, A B to the *Subſtile*, and C B to the *Axis* of the *Stile* of your *Dial*, and draw the Line C ♈♎ perpendicular to the Stile C A, —— Upon C, with 60 deg. of your *Chords*, deſcribe an Arch of a Circle and thereon ſet 23 deg. 31 min. the Declination of the Tropicks from L, both ways, to K and M, and draw C K and C M : —— This done, Out of your Dial-Plain, from the Center A, take the diſtances of every of the *Horizontal Hour-lines*, where they croſs the *Equinoctial*, (beginning with

 the

the Subſtile) and ſet thoſe diſtances upon the *Equinoctial* in the *Trigon* from the Center A, to the Points *a*, *b*, *c*, *d*, *e*, and *f*,—— Which done draw Lines from A through thoſe Points, as the Line *a* A, *b* A, *c* A, *d* A, *e* A, and *f* A, which diſtances being taken in the Compaſſes from A in the *Trigon*, and ſet upon the *Horizontal Hour-lines* on the *Dial-Plain* from the Center, ſhall there give the Points 7, 8, 9, 10, 11, 12, 1, 2, 3, 4, through which a Line drawn with an even hand from one to another without making any Angles, it ſhall be the *Tropick* next the Center, namely that of *Cancer*, —— The Points for the other Tropick of *Capricorn* may be found by taking the Diſtances from A, out of the *Trigon*, to the Interſections of the *Horizontal Hour-lines* with the Line C K, which transferred to the Plain, will give the Points 9, 10. 11, 12, 1, 2, by which the *Tropick* of *Capricorn* may be drawn : And thus have you upon this *Declining Reclining Plain*, deſcribed the *Equinoctial* and the two *Tropicks*, and by the ſame reaſon alſo you may inſert any other intermediate Parallels of the Sun's Declination.

I have been very large in the Work of this *Chapter*, but before I conclude it, I will give you notice. That,

Whereas you are directed to take out of your *Trigon* from its *Center* to the *Tropick* or other *Parallel* that you are to ſet upon your Plain, and apply that diſtance to the correſpondent *Hour-line* from the *Center* of the *Dial*: You are to *Note* —— That if you take the diſtance upon the *Trigon* from the Interſection of any *Hour-line* with the *Equinoctial*, to the *Tropick* or *Parallel* you would put upon your *Plain*; and apply that diſtance from the Interſection of the ſame *Hour-line* with the *Equinoctial* on the *Plain*, you ſhall have the ſame point upon the *Hour-line* as before : —— And this way is the better of the two. (1.) Becauſe in often applying the Compaſſes both to the Center of the *Trigon* and of the *Dial-Plain*, the Centers will be apt to rend with often applying the Compaſſes to them. 2. Becauſe this way you have ſeveral points to which you may apply the Compaſſes. And (3.) many times the Center may be very remote from the point whoſe diſtance you are to take, whereas the Equinoctial may be near at hand. And for theſe Reaſons I give you this *Advertiſement*.

CHAP. III.

Shewing how to inſcribe the Diurnal Arches, *or* Parallels *of the length of the Day on any Plain.*

THE Parallels of the *Length* of the *Day*, and thoſe of the Sun's entrance into the 12 *Signs*, are inſcribed upon all kind of Plains by one and the ſame Rules, they being in the *Sphere* the ſame *Circles*, ſo that as when you put on the *Parallels* of the Sun's entrance into the 12 Signs, you ſeek what Declination the Sun hath, and accordingly proceed as before is directed : So now for the *Parallels* of the *Length of the Day* you muſt ſeek what Declination the Sun hath at ſuch a length of the day,

as

as you would put into your Dial-Plain, which that you may do, I have here added the Rule following.

¶ Consider how much longer or ſhorter your day propoſed is than 12 hours, and take the difference, then the proportion will be,

As the Sine of 90 deg.
  Is to the Sine of half the difference.
So is the Tangent Complement of the Latitude of the place,
  To the Tangent of the Declination that the Sun ſhall have when the day is at ſuch a length as you require.

As for Example, Let it be required to know what Declination the Sun ſhall have when the day is 16 hours long in the Latitude of 51 deg. 32 min. The difference betwixt 16 hours and 12 hours is 4 hours, (or 60 deg.) the half of which is 30 deg. Therefore ſay,

As the Sine of 90 deg.	10.000000
Is to the Sine of 30 deg. which is half the difference,	9.698970
So the Tangent Complement of the Latitude 38 deg. 28 min.	9.900086
To the Tangent of the Declination of the Sun, 21 deg. 40 min.	19.599056

And ſuch Declination ſhall the Sun have when the day is either 16 hours, or 8 hours long in the Latitude of 51 deg. 32 min.

Now if the Day be above 12 hours long, the Sun hath North Declination, but if leſs than 12 hours long, he hath South Declination. I have here added a Table ſhewing what Declination the Sun hath at ſuch time that the day is either 8, 9, 10, 11, 12, 13, 14, 15, or 16 hours long, in the Latitude of 51 deg. 32 min. which Table was made by the preceding Proportion, and the like may be done for any other days and in any other Latitude.

Length of the day.	*The Sun's Declination.*	
	D	M
♑	23	31
8	21	40
9	16	55
10	11	37
11	5	55
12	0	00
13	5	55
14	11	37
15	16	55
16	21	40
♋	23	31

By which Table you may ſee that when the day is 12 hours long, the Sun hath then no Declination, but is in the Equinoctial; but when the day is either 11 or 13 hours long the Declination is then 5 deg. 55 min. and when the day is either 9 or 15 hours long, the Sun hath 16 deg. 55 min. of Declination, and ſo for the reſt, as in the Table.

For the placing of theſe Parallels of the length of the day upon any of the fore-mentioned Plains, you muſt inſert theſe Angles of Declination into your Trigon between the Tropicks; and proceed in all reſpects as before. I will therefore give you but one Example, which ſhall be in a South Plain, Declining Eaſtward 15 deg. in the Latitude of 51 deg. 32 min.

Having drawn your *Dial* with *hours*, *halves* and *quarters*, or made an *Horizontal Dial* proper for this *Declining Plain*, and put in the *Equinoctial*, proportioned your *Stile* to the *Plain* and deſcribed the two *Tropicks* as hath been already taught.

You

You must then, for the drawing of the *Parallels of the length of the day*, have recourse to the little Table before-going, and insert those Degrees of Declination into your Trigon, and from thence transfer them to your Plain.

It is to be performed in all respects as in the former Chapter for the inserting of the Signs, not at all differing therefrom; and therefore I shall forbear to give any farther instructions for the performance thereof, but shew you the Figure of a South Plain Declining Eastward 15 deg. with these Parallels drawn thereon, which will instruct more than a whole Chapter of Information. See *Figure* IX.

Note, In *Chapter* I. of this Tractate, where I shewed how to describe the Tropicks and other Parallels of Declination upon a Polar Plain, where they are Perfect Circles, I told you that I made choice of such and such Parallels of Declination, as of 11 deg. 37 min. 16 deg. 55 min. *&c.* for a reason hereafter to be given; that is, because those were the Parallels of Declination proper for those Circles when the day shall be 10 or 14: 11 or 9 hours long, and therefore, the Circles drawn through those Points of Declination are the Parallels of the Sun's Course or Diurnal Arches when the day is 13, 14, 15 or 16 hours long, as they are noted in *Figure* I.

And thus much for the drawing of the Parallels of the *Signs* and *Diurnal* Arches in all kinds of Plains. I will now proceed to shew you how some other *Astronomical Conclusions* (which are very pleasing and delightful) may be inscribed upon all sorts of Dial-Plains.

CHAP. IV.

Shewing how the Italian *and* Babylonish *hours may be Described upon all kinds of Dial-Plains.*

THE *Italians* account their hours from the *Sun's Setting*; and the *Babylonians* from his Rising, so that these kind of Hour-lines being drawn upon any Plain, you know how many hours are past since the last Setting or Rising of the Sun. The Inscription of these *Hour-lines* into any of the former Plains is very easie, the Work of the last Chapter being well understood.

Because that upon a full South or an Horizontal Plain, these Hour-lines shew themselves most uniform, I have therefore for Example sake, made choice of a full South Dial, upon which it shall be shewn how to draw both the *Italian* and *Babylonish* hours.

Your Dial being drawn and the two Tropicks and the Equinoctial thereon *Figure* X. inscribed, and also the Horizontal Line as in Figure X. you must draw in your Dial two obscure Parallels of the length of the day, one when the day is 8 hours, and the other when the day is 16 hours long: expressed in the Dial by the two pricked Arches near the two *Tropicks*, the uppermost of which is the Parallel of the Sun's Course when the day is 8 hours long, and the undermost is the Parallel of his Course when the day is 16 hours long, and the Equinoctial is the Parallel of the Sun's Course when the day is 12 hours long.

Your

	Length of the Day.		
Hours from Sun-rising.	8	12	16
1	9	7	5
2	10	8	6
3	11	9	7
4	12	10	8
5	1	11	9
6	2	12	10
7	3	1	11
8	4	2	12
9	5	3	1
10	6	4	2
11	7	5	3

Your Dial being thus prepared, and theſe Parallels thus inſerted, the Inſcription of theſe Hour-lines is very eaſie and plain to be underſtood. To begin then with the Inſcription of the *Babyloniſh* hours (which are the hours from the Sun's riſing.) Firſt, It is apparent that when the day is 8 hours long, that the Sun riſeth at 8 in the Morning, ſo that at that time, the firſt hour after the Sun's riſing is 9 in the Morning. Secondly, When the day is 12 hours long, the Sun riſeth at 6 in the Morning, ſo that at that time, the firſt hour after the Sun's riſing is 7 in the Morning. Thirdly, When the day is 16 hours long, the Sun riſeth at 4 in the Morning, ſo that the firſt hour after his riſing is 5 in the Morning, as plainly appeareth by this Table: by which you may perceive that when the day is 8 hours long, the ſeventh hour from Sun riſing is 3 in the Afternoon. When the day is 12 hours long, the ſeventh hour from the Sun's riſing is 1 in the Afternoon. And when the day is 16 hours long, the ſeventh hour from the Sun's riſing is 11 before Noon, as by this Table doth evidently appear. And therefore a ſtreight Line drawn in your Dial through thoſe Points where the common Hour-lines of your Dial croſs the reſpective Parallels of the days length, ſhall ſhew the true quantity of hours ſince the Sun's riſing at all times of the Year, which is the *Babyloniſh* hour.

For *Example*, Let it be required to draw the ſeventh hour from the Sun's riſing in your Dial. Firſt, By the Table you ſee, that in the Parallel of 8 hours for the length of the day, the ſeventh hour from the Sun's riſing is 3 in the Afternoon, therefore obſerve where the Hour-line of three croſſeth the Parallel of 8 hours, which is at *a*. Secondly, By the Table you ſee that in the Parallel of 12 hours for the length of the day, the ſeventh hour from Sun riſing is then 1 in the Afternoon, wherefore obſerve where the Hour-line of 1 croſſeth the Equinoctial, which is at *b*. Thirdly, By the Table you ſee that in the Parallel of 16 hours, for the length of the day, the ſeventh hour from the Sun's riſing is 11 before Noon, therefore obſerve where the Hour-line of 11 croſſeth the Parallel of 16 hours, which is at *c*: then draw the ſtreight Line *a b c*, which ſhall be the ſeventh *Babyloniſh* hour, or the ſeventh hour from the Sun's riſing all the Year long.

And by this Rule, and the help of the Table, you may draw all the other hours from Sun riſing, as you ſee them drawn in the Figure, and put Numbers to them, as you ſee there done; But to remove all doubts that may ariſe in the performance thereof, obſerve the following Notes.

Note 1. That if any of the Points you are to make uſe of for the drawing of any of theſe hours fall without your Plain, you muſt in this caſe extend your Hour-line, Parallel and Equinoctial, beyond the limits of your Dial-plain, and there make uſe of the Points, but you need extend the Line you draw no farther than the bounds of the Plain, as here in the Figure you ſee the firſt hour from Sun riſing croſſeth not the Equinoctial and the Hour-line of 7 within the Plain, but if the Equinoctial and the Hour-line of 7 were extended, it would croſs.

Note 2. That if any of the three Points you are to make uſe of do ſo far exceed the limits of your Plain, that it will be either impoſſible (or at leaſt very troubleſome) to extend the Hour-lines ſo far, then in that caſe any two of the three Points will ſufficiently ſerve the turn.

Note 3. That as the hours from Sunr-iſing were put into the Plain, by the ſame Rule may the hours from Sun-ſetting (or *Italian* hours) be inſerted, the difference being only in the numbring of them; the hours from the Sun's riſing being numbred from the Weſt ſide to the Horizontal Line by 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11, and the hours from the Sun's ſetting are denominated from the Eaſt ſide of the Horizon, and numbred backwards by 23, 22, 21, 20, 19, 18, 17, 16, 15, 14, and 13, as in Figure X. doth evidently appear.

Note 4. That theſe *Italian* and *Babyloniſh* hours inſcribed on all Plains by help of this little Table, and the Rules and Cautions delivered in this Chapter, and therefore more Examples were ſuperfluous: Only for your further ſatisfaction have recourſe to Figure IV, and Figure I, where theſe Hour-lines are inſcribed upon Direct *Polar* and Direct *Equinoctial* Plains.

A Corollary ariſing from the Work of this Chapter.

The Parallels or Hour-lines from the Sun's *Riſing* or *Setting* being inſcribed upon any Plain, there will, by their Correſpondent Interſections one with another, be Points produced, through which, if Lines be drawn with an even hand, the ſame ſhall be Parallels of the Length of the day: So the Pricked Line 5 *c* 19, in Figure X, is the Parallel of the Sun's Courſe when the day is 16 hours Long; and the Pricked Line ⊙ *a* ⊙ in the ſame Figure X, is the Parallel when the day is 8 hours Long. So the Pricked Curved Lines in the Equinoctial Dial, Figure IV, are the Parallels of the Sun's Courſe when the day is 8. 9. 10. 11. 12. 13. 14. 15 and 16 hours Long. Alſo, the Circular Line noted with 15. 15. 15. in the Polar Dial, Figure I. is the Parallel of the Sun's Courſe when the day is 15 hours Long: and thus may Points be found whereby to draw the *Diurnal Arches* upon all Plains whatſoever.

CHAP. V.

Shewing how the Jewiſh *or Old Unequal Hours may be drawn upon any Plain.*

IT was the Cuſtom of the Ancients to divide their Day and alſo their Night (whether long or ſhort) into 12 equal parts, beginning their *Day* at the *Sun's riſing*, and their *Night* at the *Sun's ſetting*: So that 12 of the Clock at Noon was always the *Sixth* hour of their day, and 12 at night was always the *Sixth* hour of their *Night*, and according to this Diviſion were their Dials drawn; ſo that all the Summer the hours of their day were longer than the hours of their night; and all the Winter, the hours of their night were longer than thoſe of their day, and when the Sun is in the Equinoctial, then the hours of their day and night were equal, and the ſame with thoſe of our Account, but at all other times of the Year different.

The

The inſcribing of theſe hours into all kind of Plains is very eaſie, being much like the drawing of the *Babyloniſh* and *Italian hours* before taught.

Having therefore drawn your Dial with the Hours, Halves, and Quarters, and alſo drawn the two Tropicks and the Parallels of the length of the day thereupon, as you ſee done in Figure IX, which is a South Plain declining Eaſtward 15 deg. Then make choice of two Parallels of the length of the day, which muſt be both of them equidiſtant from the *Equinoctial*, which let be the Parallels of 9 hours and 15 hours, both which are three hours diſtant from the *Equinoctial* on either ſide thereof, and theſe two Parallels are the moſt convenient for this purpoſe, becauſe the *Jewiſh hours*, will fall (in theſe two *Parallels*,) juſtly upon the *Hours*, *Halves* and *Quarters* of the *Common Hour-lines:* and ſo be the eaſier drawn. Now the Points through which every one of the *Jewiſh hours* muſt paſs is ſhewed by this little Table, wherein you may ſee that the Firſt *Jewiſh hour* muſt be drawn through 5 hours 45 minutes (or 5 hours three quarters) in the Parallel of 15, through 7 hours in the Equinoctial, and through 8 hours and a quarter in the Parallel of 9 hours.

Jewiſh hours.	*The Parallel of 15 hours.*		Equinoctial.	*The Parallel of 9 hours.*	
	H	M		H	M
1	5	45	7	8	15
2	7	0	8	9	0
3	8	15	9	9	45
4	9	30	10	10	30
5	10	45	11	11	15
6	12	0	12	12	0
7	1	15	1	0	45
8	2	30	2	1	30
9	3	45	3	2	15
10	5	0	4	3	0
11	6	15	5	3	45
12	7	30	6	4	30

In like manner, the Second *Jewiſh hour* muſt be drawn in your Plain through 7 of the Clock in the Parallel of 15: through 8 a Clock in the Equinoctial: and through 9 of the Clock in the Parallel of 9 hours, and ſo of all the reſt, according as you ſee in this Table, and as you may perceive them drawn in the South declining Plain before mentioned Figure IX. And through thoſe hours and quarters of hours which this Table expreſſeth, muſt the Old unequal or *Jewiſh* hours be drawn, in all Plains whatſoever; whether Direct, Declining, or Reclining and Declining, of which you have another Example of theſe hours drawn upon the Polar, or South Reclining Plain, Figure IV. Theſe things are called by ſome the *Planetary Hours*, but they are very different from them, for theſe reſpect the equal Diviſion of the *Equinoctial*, as the other do of the *Ecliptick*.

CHAP. VI.

Shewing how to draw the Azimuths, *or* Vertical Circles *on all ſorts of Plains.*

THE Azimuths are great Circles of the Sphere, meeting together in the *Zenith* and *Nadir* of the *Place:* They have the ſame Relation or Habitude to the *Horizon*, as the *Meridians* or *Hour-circles* have to the *Equinoctial.* They are variouſly inſcribed on all *Plains* according to their Situation. In the *Horizontal* Plain they meet in a Center with equal Angles: As the Hour-lines did in the Equinoctial Plain. In all *Upright* Plains, whether

whether *Direct* or *Declining*, they are Parallel to the *Meridian* or Line of 12. And in all *Reclining Plains* they meet together in a Point which is the Zenith of the Place, but with unequal Angles. These Azimuths being great Circles in the Sphere; are therefore streight Lines, and may be described upon all sorts of Plains as followeth.

SECT. I. *On the Horizontal Plain.*

IN the Horizontal Plain these Azimuths are most easily inserted, for your Dial being drawn, with the Tropicks thereon, you have no more to do, but upon the foot of the Perpendicular Stile to describe a Circle, which you may divide into 32 equal parts (beginning at the Meridian) answering to the 32 Points of the *Mariner's Compass*; Or else you may divide the same Circle into 90 equal parts, according to the *Astronomical* Division, and through each of those Points draw streight Lines from the foot of the Stile, and set Numbers or Letters to them, either by 10, 20, 30, 40, *&c.* if you divide the Quadrant into 90, or else by South, S by W, S S W, S W by S, *&c.* if you divide the Circle according to the Mariner's Compass; An Example of these Lines drawn upon an Horizontal Dial, you shall find at the end of the Tenth Tractate, *Of Projective Dialling.*

SECT. II. *On East or West Erect Direct Plains.*

Figure II. YOur Dial being finished, Upon the Point E, of the Horizontal Line M E N in your Dial, raise the Perpendicular E Q equal to the Line E G in your Dial, and on Q as a Center, describe the Quadrant Q E L, and divide it into eight equal parts, representing one quarter of the *Mariner's Compass*, and from the Center Q draw Lines through each of those Divisions, extending them till they cut the Horizontal Line M E N in the Points ⊙ ⊙ ⊙ ⊙ ⊙ ⊙, from which Points draw Lines perpendicular to the Horizontal Line M E N, and they shall be the *Azimuths* or *Points* of the *Compass* between the *East* and the *South.*—— Now for those *Azimuths* which fall between the *East* and the *North*, namely, E by N.—E N E—N E by N.— the same distances being set upon the Horizontal Line from E, towards the left hand, as the three first Azimuths E by S —— E S E —— S E by E were toward the right hand, shall give the 3 Points ⊙ ⊙ ⊙ on the left hand of E, through which Points also Lines drawn perpendicular to the Horizon, shall be the *Azimuths* between the *East* and the *North*, *viz.* so many of them as your Plain is capable to receive, as in Figure II.

¶ Here note, That as the *East Dial* sheweth all the *Morning* hours from Sun *Rising* to the *Meridian* : and the *West Dial* sheweth all the *Afternoon* hours from the *Meridian* to his *Setting* : so doth the *East Dial* shew all the *Azimuths* from the Sun's *Rising* till *Noon*, and the *West Dial* all the *Azimuths* from *Noon* till *his Setting.*

SECT. III. *In the full North and South Erect Plains.*

THE drawing of the *Azimuths* upon the full North or South erect Plains is very little different from the drawing of the same Circles upon the East or West Plains. But for Example, Let it be required to draw the Azimuths

muths upon a full South Dial. The Tropicks and the Equinoctial being drawn together with the Horizontal Line A L B. Take in your Compasses the length of the Perpendicular Stile of your Dial L S, and set it upon the Meridian Line of your Dial, from L to ⊙, and upon the Point ⊙ as a Center, describe the Semicircle E L F, and divide each Quadrant thereof, namely E L and L F into 9 equal parts (each Quadrant representing one quarter of a Great Circle, which is 90 degrees) For in this *Example* I have put in the *Azimuths* according to the *Astronomical Account* of them, as 10, 20, 30, *&c.* from the *Meridian*, and not according to the *Mariner's Account* by *Points* of the *Compass*) and through each of those Divisions draw Lines from the Center ⊙ till they cut the Line A L B in the Points *m*, *n*, *o*, *p*, *q* and *r*, through which Points draw Lines parallel to the Meridian or Line of 12, they shall be the true *Azimuths* upon your Plain, and so these Azimuths are according to the *Astronomical Account* by 10, 20, 30, 40, *&c.* and not by the Mariner's Account by Points of Compass, as in the East Dial they were. *Figure* V.

SECT. IV. *On Erect* Declining *Plains.*

IN upright Declining Plains the Azimuths are easily inscribed, little differing from the former. Draw therefore your Dial, which we will suppose to be the South Declining Plain before used, Declining from the South Eastward 15 degrees. As Figure IX. *Figure* IX.

Your Dial being drawn with the Equinoctial, Tropicks, and Horizontal Line thereon inscribed; Upon the Horizontal Line D B E in your Dial, on the Point B raise the Perpendicular B C, making B C equal to B O the perpendicular Stile in your Dial: then on the Point C as a Center, describe the Semicircle R B S; This done, Lay a Ruler upon C, unto ⊙, where the Hour-line of 12 and the Horizontal Line do cross each other, and where it cuts the Semicircle R B S, begin to divide it into sixteen equal parts at the Points * * *, *&c.* then from the Center C draw Lines through each of those Divisions till they cut the Horizontal Line D E in the Points *a b c d e f g h i k* and *l.* —— Lastly, Through these Points *a b c d e f g h i k* and *l* draw Lines parallel to the Meridian, which Lines shall be the Azimuths required, which you must number according to the Situation of the Plain, *viz.* the *Western Azimuths* on the *East* side of the *Meridian*, and the *Eastern Azimuths* on the *West* side thereof, as you see them numbred in Figure IX.

SECT. V. *Upon Direct North, and South Recliners.*

IN all these *Plains*, because the *Zenith* of the *Place* cutteth these Plains obliquely, making oblique Angles therewith, there is in all these Plains two *Points* to be found, before the *Azimuths* can be drawn: The one is the *Zenith of the Plain*, (which is the foot of the Perpendicular Stile;) The other is the *Zenith of the Place*, (which is the Point upon the Plain where all the *Azimuths* must meet, with unequal Angles, as the *Hour-lines* upon all Dial-plains do in the *Poles*, except in the Polar Plain, where they meet with equal Angles.) And here note, That the *Zenith Point* of the Place, always falleth upon the *Meridian*, or 12 a Clock Hour-line of the Dial.

I. *Upon Direct Polar or Equinoctial Plains.*

To find these two Points upon a *North* Plain Reclining from the *Zenith* 51 deg. 32 min. equal to the Latitude of the Place, the Complement thereof is 38 deg. 28 min. and such a Plain is the forementioned *Polar Dial*, Figure I.

Figure I. In the *Trigon* belonging to this Polar Dial, the Line K D is made equal to the height of the Perpendicular Stile in the Dial A X, Wherefore, Let K D be made *Radius*, then M C (being Perpendicular to it) is a Tangent Line thereto. Wherefore, upon K, as a Center, describe an Arch of a Circle L D V, upon which set 51 deg. 32 min. the Reclination of the Plain from D to L, and set 38 deg. 28 min. the Complement of the Plain's Reclination from D to V, and through the Points L and V, draw the Lines K L M, and K V T.

So, K D being equal to the length of the Perpendicular Stile, D M shall be the *Tangent*, and K M the *Secant* of the *Plain's Reclination*: And D T shall be the *Tangent*, and K T the *Secant* of the *Complement* of the *Plain's Reclination.*

These Lines being drawn upon your *Trigon*, take D M the Tangent of the Plain's Reclination, and set it upon the Meridian Line of your Dial-plain from A the foot of the Perpendicular Stile, to S, so shall S be the Point through which the proper Horizontal Line of the Plain P S Q must be drawn.—— Also, out of your *Trigon* take D T, the Tangent Complement of the Plain's Reclination, and set that distance upon the Meridian Line of your Dial-Plain, from A the foot of the Perpendicular Stile, to ⊙, so shall ⊙ be the *Zenith* of the Place, and the Center where all the *Azimuths* must meet.

Again, Take K M, (the Secant of the Plain's Reclination) out of your *Trigon*, and making that *Radius*, set one foot of your Compasses in A, the Center of the Dial, and describe the Semicircle *m* S *n*, which divide into 16 equal parts, for one half of the *Mariner's Compass* if you will put in the *Azimuths* according to that Account (as here they are) Or into 90 deg. each *Quadrant* (if you will) according to the Astronomical Account. Then lay a Ruler upon A, and the several Divisions of the Semicircle *m* S *n*, and it will cut the Horizontal Line P S Q (which is also a Tangent Line to the Semicircle *m* S *n*) in the Points * * * *.

Lastly, Lay a Ruler to ⊙, which is the *Zenith* of the Place, and to every of these Points * * *, So shall Lines drawn by the Side of the Ruler (as the Pricked Lines in Figure I. are) be the *Azimuth* Lines desired. Which must be numbred from the *Meridian* towards their proper Coast, as in Figure I. Upon all other Plains the *Rule* following is General.

II. *Upon* North *and* South Reclining Plains.

The *Perpendicular Stile* being made the *Radius*, the Meridian Line is a Tangent Line thereunto; and the *Vertical* or *Zenith* Point, in which all the *Azimuths* must meet, must always be the *Tangent of the Complement of the Plain's Reclination*, and must be set upon the Meridian Line, from the foot of the Perpendicular Stile *downwards* in *Recliners*, but *upwards* (or above the foot of the Perpendicular Stile) in the opposite *Incliners* —— Also, The *Horizontal Point* in these *Reclining Plains*, must be the *Tangent of the Plain's Reclination*, set from the foot of the

Perpen-

Perpendicular Stile upon the Meridian *upwards* in *Reclining Plains*, but *downwards* in the *Incliners*. And the *Horizontal Point* being found, the *Horizontal Line* drawn through the same must be always *Parallel* to the *Hour-line* of *Six*.

In *Equinoctial Plains*, whether *Direct* or *Declining*, the *Azimuth Circles* meet at the *Vertical Point*, with *Un-equal Angles*, and therefore, one other Point must be found to draw each *Azimuth* by:

And that other Point may be most conveniently had, either in the *Horizontal Line* of the *Plain*, or in the *Equinoctial*: And those Points of *Intersection* with the *Equinoctial*, may be found by this Proportion,

As the Sine of 90 deg.
Is to the Sine of the Latitude,
So is the Tangent of the *Azimuth* from the *Meridian*,
To the Tangent of the *Equator's Distance* from the *Meridian*.

So the *Latitude* being 51 deg. 32 min. The 10th *Azimuth* from the *Meridian* will be found to be 7 deg. 50 min. from the *Meridian* upon the *Equator*: Or, the *Azimuth* of 11 deg. 15 min. one *Point* of the *Compass* will be found to be 8 deg. 51 min. from the *Meridian* upon the *Equator*, and the rest as in these Tables.

Azimuth.		*Equinoct. Distance.*	
D	M	D	M
10	0	7	50
20	9	15	54
30	0	24	20
40	9	33	18
50	9	43	0
60	9	53	35
70	9	65	3
80	0	77	18
90	0	90	0

Points.			*Equinoct. Distance.*		*Points Names.*
	D	M	D	M	
1	11	15	8	51	S *by* E
2	22	30	18	58	S S E
3	33	45	27	36	S E *by* S
4	45	0	38	2	So. East
5	56	15	49	30	S E *by* E
6	67	30	62	6	E S E
7	78	45	75	44	E *by* S
8	90		90	0	East.

I intended to have inserted the *Azimuths* (by this Rule) into Figure IV. but it being incumbred with *Furniture* enough already, I omitted them: These *Directions* being sufficient to supply that Defect.

SECT. VI. *Upon East or West Recliners.*

IN all those Plains, the *Hour-line* of XII. (which is the *Meridian of the Place*) and the *Substilar Line* (which is the *Meridian of the Plain*) are not both one Line, (as in all the other *Examples* they were) but two several Lines: You must therefore (to instance in a *West Dial* Reclining 40 deg. as in Figure XII.) First, Find the *Vertical* or *Zenith Point*, where the *Azimuths* are to meet, and Secondly, the *Horizontal Point*, through which the *Horizontal Line* must pass. *Figure* XII.

First,

First, From the foot of the Perpendicular Stile, as at A, let fall a Perpendicular to the Meridian of the Place or Hour-line of XII. [which Line in all East and West Recliners is Parallel to the Horizon, as in North and South Upright Plains it is Perpendicular thereunto] Let this Perpendicular Line be V A O, so V shall be the *Vertical* or *Zenith Point*, where all the *Azimuths* must meet, and O shall be the *Point* through which the *Horizontal Line* must be drawn, parallel to the Hour-line of 12, as the Line D O E, and (if there be no former Errour in your Work) this *Horizontal Line* will also pass through the Intersection of the *Equinoctial Line* with the *Hour-line* of *Six*. These Points you see are easily found in these Plains, by drawing of one Line only, namely V A O; But more artificially thus: The Line V A O being drawn at full length, Upon the Point A Erect a Perpendicular A H, making A H equal to A B the length of the Perpendicular Stile. Then making A H the *Radius*, V A O shall be a Tangent Line thereto: Upon H describe the Arch of a Circle L A K, and upon it, set off 40 deg. the Plain's Reclination from A to K, and 50 deg. the Complement thereof from A to L: and draw the Lines H K and H L, till they cut the Perpendicular Line V A O, which they will do in the Points V and O, and so is A O the Tangent of the Plain's Reclination 40 deg. and A V the Tangent Complement of the Reclination 50 deg. and by this means also you have found the *Vertical* and *Horizontal* Points O and V.

This done, take H O (which is the Secant of the Plain's Reclination 40 deg.) and with that distance, upon A, the foot of the Perpendicular Stile, describe a Semicircle P Q S, which divide (each quarter thereof) into Eight equal parts, beginning at Q: where the Vertical Line V A (extended) cuts the Semicircle: A Ruler laid from Q, to each of those parts, will cross the *Horizontal Line* D O E (extended where need requires) in the Points * * *, *&c.*

Lastly, A Ruler laid to V, the *Zenith Point* and every of these Marks * * * in the *Horizontal Line*, if you draw Streight Lines thereby they shall be the *Azimuths* Required.

SECT. VII. *Upon North or South Declining Reclining Plains.*

THE inserting of this kind of Furniture into Declining Reclining Plains, differeth little from the inserting the same Furniture into East or West Recliners; For having drawn your Dial, proportioned your Stile to your Plain, described the two Tropicks and Equinoctial, as also the Horizontal Line proper to the Plain: You may proceed to the Inscription of the Azimuth or Vertical Circles, in manner following:

Figure XIII. First, From the foot of the Perpendicular Stile at K let fall a Perpendicular to the Horizontal Line of the Plain, as V K H, upon K raise a Perpendicular K N, making K N equal to F K the perpendicular Stile; which Line K N, make a *Radius*, and upon N as a Center, describe an Arch of a Circle, and upon it set 35 deg. the Complement of the Plain's Reclination from K to *b*, and draw the Line N *b* V. Also set 55 deg. the Reclination from K to *a*, and draw the Line N *a* H: So shall K H be the Tangent, K V the Tangent Complement of the Plain's Reclination, and consequently H N, the Secant of the Reclination.

Secondly, Make H O equal to H N, and upon O as a Center describe the Semicircle P H D, so is the Horizontal Line a Tangent Line thereto.

Thirdly,

Thirdly, Obſerve where the Hour-line of 12 cuts the Horizontal Line, which is at S: A Ruler laid from O to S will cut the Semicircle in Q, at which Point begin to divide the Semicircle into (either) 16 equal parts for the Points of the Compaſs, or (as I have here done) into 18 equal parts, at the Points ⊙ ⊙ ⊙, *&c.* each containing 10 deg. as Aſtronomers account.

Fourthly, The Semicircle being thus divided, lay a Ruler to Q, and every of the Diviſions ⊙ ⊙ ⊙, *&c.* and where the Ruler croſſeth the Horizontal Line, make Marks or ∗ ∗ ∗.

Laſtly, If from the Point V, right Lines be drawn through theſe Marks or ∗ ∗ ∗, they ſhall be the Azimuths proper for the Declining Reclining Plain.

CHAP. VII.

Of the Almicanters, *or Circles of* Altitude, *and how to inſcribe them upon all ſorts of Plains.*

IN the Sphere, the *Almicanters* or Circles of *Altitude*, have the ſame habitude or relation to the *Azimuth* or *Vertical Circles*, as the *Parallels* of *Declination* have to the *Meridians* or *Hour-circles:* And therefore, As the *Equinoctial* it ſelf, and alſo all the *Parallels* of *Declination* in a *Polar Dial*, (as Figure I.) are perfect *Circles*, ſo are the *Almicanters* perfect Circles upon *Horizontal Plains.*

The Inſcription of theſe into all ſorts of Plains, is (in a manner) the ſame with the Inſcription of the Parallels of Declination: Only, whereas inſcribing the Tropicks and Parallels of Declination, you took the Hour-lines out of your Plain and put them into a *Trigon*; ſo in the Inſcription of theſe, you muſt take the *Azimuth* Circles out of your Plain, and put them into a *Trigon*, and from thence transfer them back again to your Plain as you did the other: And therefore, As the *Hour-lines* (in the other) muſt be firſt drawn upon the Plain, ſo (in this) muſt the *Azimuths* be firſt inſcribed as in the preceding Chapter hereof was ſhewed how to do: And becauſe theſe Almicanters are ſmaller Circles of the Sphere, as the Tropicks and Parallels of Declination were, they will (by the 3d. Affection) alſo be *Conick Sections*: Now the manner how to inſcribe them upon all ſorts of Plains, ſhall be ſhewed in this Chapter.

SECT. I. *Upon* Vertical, *or* Horizontal *Plains.*

THeſe Plains lie Parallel to the Horizon, and have the Zenith Point for their Pole, ſo that the foot of the Perpendicular Stile muſt be the Center upon which (in theſe Plains) the Almicanters muſt be deſcribed.

For the Numeration of theſe Circles, there are Two ways which are moſt in uſe. The one is according to Degrees and Minutes of Altitude; the other according to the Proportion that the height of any Upright Object bears to the Shadow of it.

I. *By Degrees and Minutes of Altitude.*

The Dial being drawn, with the Equinoctial and the two Tropicks upon it (to limit the rest of the Work) make the Perpendicular Stile of the Dial a *Radius*, and upon the top thereof (as a Center) describe a Semi-circle (or Quadrant) then will the Meridian or 12 a Clock Hour-line be a Tangent Line thereunto.——— Divide this Quadrant into 90 equal parts or degrees, (or into each 5 or 10 deg. which may be sufficient) and from the top of the Stile draw Lines through those Divisions, till they cut the Meridian of the Dial, And through those Divisions upon the Meridian Line, Circles described upon the foot of the Perpendicular Stile, shall be the Circles of the Sun's Altitude when the Sun is so many degrees high as you divided your Quadrant into parts, whether every 5th. 10th. or any other number of Degrees of Altitude.

II. *By the Proportion that Upright Objects bear to the Length of their Shadows.*

If you make the length of the Perpendicular Stile a *Radius*, as you must (always) do, let it be divided into 10 (or rather 100) equal parts: Then, if you take the whole length thereof in your Compasses, and set it from the foot of the perpendicular Stile, upon the Meridian Line, and through that point describe a Circle, the point of the Shadow of the *Apex*, or top of the perpendicular Stile, when (at any time) that toucheth that Circle, the Shadows of all Upright Objects shall be equal to their Altitudes or Heights —— Likewise if twice the length of the perpendicular Stile be set upon the Meridian, from the foot of the Stile, a Circle described through that point, when the Shadow of the top of the Stile cometh to touch that Circle, then are the Shadows of all Upright Objects double to their heights: —— Likewise if Once, Twice, Thrice and an half, the length of the perpendicular Stile be set upon the Meridian Line from the foot of the Stile, and Circle, described through those points, the Shadow of the *Apex* coming to touch any of them, the length of Shadow shall be equal to either Once, Twice, Thrice and an half the height of the Object; These Circles may have written upon them 10, 20, 30, 40, &c. degrees of Altitude. Or *Æqualis*, *Dupla*, *Tripla*, &c. An Example of an Horizontal Dial with these Circles described upon it you have in the Ninth Tractate hereof, *Page* 120.

But if you would put in more minute parts of the Proportion of Objects to their Shadows, you must first enquire what Altitude the Sun must have to make the Shadow be in such proportion to the Object, as shall be required; and to find that, this is the Analogy, or Proportion: For,

As the parts of the Shadow,
    Are to the parts of the Gnomon; or perpendicular Stile;
So is the Tangent of 45 deg. or *Radius*,
    To the Tangent that the Sun's Altitude must be, to make the Shadow so long, as shall be required.

Example, *Suppose I would know how high the Sun must be, to make the Shadow to be two times and an half the length of the Gnomon:*

The

The Gnomon or perpendicular Stile, we will ſuppoſe to be divided into 100 equal parts, and meaſuring the Shadow thereby, you find that to be 350 parts, that is 3 times and an half, the length thereof; Say,

As 350, the parts of the Shadow,	2.54407
Are to 100, the Length of the Gnomon;	2.00000
So is the Tangent of 45 deg. or *Radius*,	10.00000
	12.00000
To the Tangent of 15 deg. 57 min.	9.45593

And ſuch Altitude muſt the Sun have to make the length of the Shadow to be Three times and an half the length of the Objects, height.

And according to this Proportion may you find any other Proportional Parts, the moſt uſual I have here ſet down, with their Altitudes ready Calculated.

If you would have the length of the Shadow, to be in proportion to the height of the Object, as		*Is to*		*The Sun's Altitude must be*	deg.	min.
	10		1		7	07
	6		1		9	27
	5		1		11	18
	4		1		14	02
	3		1		18	26
	2		1		26	33
	3		4		33	41
	2		3		36	52
	5		4		38	35
	4		5		45	00
	3		4		51	29
	4		3		53	07
	3		5		56	19
	1		2		58	02
					63	21

And on the contrary, If you would know what Altitude the Sun muſt have to make the Shadow of what Length you ſhall Deſire; then uſe the following Proportion:

As for Example, *What Altitude muſt the Sun have to make the Shadow to be 5 times the Length of the Gnomon?*

As 100, the Length of the Gnomon;	2.00000
Is to the Radius, Tang. 45 deg.	10.
So is 500 (the Length of the Shadow required	2.69897
	12.69897
To the Tangent of 78 deg. 42 min.	10.69897

Whoſe Complement is 11 deg. 18 min. And ſuch Altitude muſt the Sun have to make the Shadow 5 times as long as the Gnomon. And ſo of any other Length; As in the following Table.

A Table

A Table of the Proportion that the Shadow hath to the Length of a Perpendicular Gnomon, *useful for the inserting of such* Almicanters *into* Sun-Dials.

When the Sun's Altitude is D	M	*The Shadow of the Gnomon is*	*Times as much, as the length of the Gnomon.*
1	7	50	
2	5	20	
5	42	10	
7	7	8	
9	27	6	
11	18	5	
14	2	4	
18	26	3	
26	34	2	
30	58	*As* 5 *to* 3	
33	41	*As* 3 *to* 2	
36	52	*As* 4 *to* 3	
38	40	*As* 5 *to* 4	
45	00	*Equal*	

But, when the Sun's Altitude is D	M	*The Shadow of the Gnomon is*	*Times less than the Gnomon.*
45	0	*Equal*	
51	20	*As* 5 *to* 4	
53	7	*As* 4 *to* 3	
56	19	*As* 3 *to* 2	
59	2	*As* 5 *to* 3	
63	26	2	
71	34	3	
75	58	4	
78	42	5	
80	33	6	
82	53	8	
84	18	10	
87	10	20	
88	54	50	

SECT. II. *Upon* Upright *Plains, either* Direct *or* Declining.

UPon all these Plains, having first inscribed the *Tropicks*, *Equinoctial*, and *Horizontal* Line, together with the *Azimuths*, proper to the Upright Plain, whether it be *Direct* or *Declining*,—— Upon the foot of the perpendicular Stile, erect a Perpendicular to the Horizontal Line of the Plain: equal in length to the perpendicular Stile of the Dial,—— As for *Example*.

Figure XI. In the Upright Declining Plain, Figure XI. Upon the foot of the perpendicular Stile at A, Erect the Perpendicular A O equal to A B, and perpendicular to C D, the Horizontal Line of the Plain,—— Then prepare a *Trigon*, (as under the same Figure XI.) in this manner.

First, Draw a right Line E F, and upon E as a Center, describe an obscure Arch of a Circle G F H, on both sides of the Line E F, because it is a Declining Plain, and the Azimuths on each side of the foot of the Perpendicular upon the Horizontal Line are not equidistant therefrom, (whereas, if it had been a Direct Plain, one half of the *Trigon* would have served the turn) into these two Arches F G, and F H, from the point F, by help of the Scale of *Chords*, insert such *Arches*, as you intend to put *Circles* of *Altitude* upon your Plain. I have made choice of these, *viz.* 10, 20, 30, 40, 50 and 60, which I put into the *Trigon* from F, on both sides thereof towards H and G, at the Points *a b c d e* and *f*, and so draw the Lines E *a*, E *b*, E *c*, E *d*, E *e* and E *f* on both sides, setting the Numbers proper to them towards the ends of them: and these Lines I shall for the future call the *Lines* of *Altitude*.

Secondly, Take the length of the perpendicular Stile A B (to which A O is equal) out of your Dial, and set it upon your *Trigon* from E to M, and through the point M draw the Line M L, perpendicular to E F. So shall the Line E F of your *Trigon*, represent the *Horizontal Line* of your Dial,

and

and the perpendicular Line L M that *Azimuth* or *Vertical Circle* which paſſeth through the foot of the perpendicular Stile in your Dial.

Thirdly, Out of your Dial-Plain, from the point O, the top of the perpendicular Stile, take the diſtances to the ſeveral points 20, 30, 40, 50, 60 and 70 (that is, where thoſe *Azimuth* or *Vertical Circles*, croſs the Horizontal Line of your Plain C D) on the Weſt ſide of the Dial, and ſet them upon the Line E F of the *Trigon*, to the points 2, 3, 4, 5, 6 and 7, on the Weſt ſide of the *Trigon*, and through thoſe points, draw right Lines (all of them) perpendicular to the Horizontal Line of your *Trigon* E F, ſetting the Numbers to the ends of them as they are numbred in the Dial-plain, *viz.* 20, 30, 40, 50, 60 and 70: So ſhall theſe Lines 20. 2: 30. 3: *&c.* be the Azimuth Lines upon your *Trigon.* —— In the ſame manner deal with the Eaſt Side of the Dial, by taking the diſtances from O, to the Interſections of the Azimuths with the Horizontal Line, ſetting them from E to *g*, *h*, *i*, *k*, *l* and *m*, and drawing the Azimuth Lines through the points, *g*, *h*, *i*, *&c.* on your *Trigon*, perpendicular to the Line E F, ſetting their reſpective Names or Numbers to them at the ends of them.

Your *Trigon* being thus prepared, the next Work will be to transfer the *Lines* of *Altitude* from the *Trigon* to the *Plain*, which to do,

Fourthly, Suppoſe, I would transfer the Parallel of the *Sun's Altitude* for 30 deg. from the *Trigon* to the *Plain:* —— Firſt, on the Weſt Side: The Parallel of 30 deg. of Altitude is repreſented by the Line E *c* 30, (1.) Obſerve where the Parallel of Altitude croſſeth the Azimuth of 70, and from that point (2.) take the diſtance to the Line E F, which diſtance (3.) ſet upon the Azimuth Line of 70 upon your Plain from 70 to *n*, ſo ſhall *n* be the point upon the 70th. Azimuth of your Plain, through which the Parallel of 30 deg. of *Altitude* muſt paſs: In like manner,

From the Point where the Line of 30 deg. of Altitude, croſſeth the Azimuth Line of	60 50 40 30 20 *Subſt.*	*Take the diſtance to the Horizontal Line of your* Trigon E F, *and ſet that diſtance upon your Dial-plain upon the Azimuth Line of*	60 50 40 30 20 *Subſt.*	*to*	*o* *p* *q* *r* *s* *t*

Alſo, on the Eaſt Side of the *Trigon*, and the Eaſt Side of the *Dial:*

From the Point where the Line of 30 deg. of Altitude, croſſeth the Azimuth Line of	10 *South* 10 20 30 40	*Take the diſtance to the Horizontal Line of your* Trigon E F, *and ſet that diſtance upon your Dial-plain, upon the Azimuth Line of*	10 *South* 10 20 30 40	*to*	*v* *w* *x* *y* *z* *æ*

Then a Line drawn with an even hand, through the points *n o p q r s t v w x y z æ*, ſo that it make no Angles, that Line, ſo drawn, ſhall be the *Parallel* of the *Sun's Altitude* of 30 deg. upon your *Plain:* And the like courſe is to be taken for all the reſt of the Parallels of Altitude, as the Scheme, Figure XI. will better inform you than many words.

SECT. III. *Upon* East *and* West Recliners, *as also upon* North *and* South Declining Reclining *Plains*.

IN these Plains, the Meridian of the Plain (or Substile) and the Meridian of the Place (or Hour-line of 12) are two different Lines; Therefore (as in the describing of the Parallels of the Signs) you took the Substile or Meridian of the Plain, for 12 a Clock, and drew Horizontal Hour-lines on either side thereof, to facilitate the Work, (as in *Chap. II. Sect. IV. Fig. VII.*) So for the Inscription of the *Almicanters* or *Parallels* of *Altitude*, take the *Azimuth* which is perpendicular to the Plain (which will be always equal to the Declination) and equal on both sides thereof (from the foot of the perpendilar Stile) set off such Azimuths as you intend (whether points of the Compass or 10, 20, 30, *&c.*) for these must be drawn obscurely, that they may may be wiped out again, if need be.

Figure XIV. Your Dial being thus prepared (which is a South Plain Declining 30 deg. and Reclining 55 deg.) with the *Horizon*, *Tropicks*, *Equinoctial*, and obscure *Azimuths*, as in *Figure XIII.* prepare a *Trigon* in this manner.

First, Draw a right Line F B, and upon F (as a Center) describe an Arch, or Quadrant, of a Circle, as C D, and upon it set such degrees of Altitude as you have a mind to inscribe upon your Plain (I have here made choice of 10, 20, 30, 40, 50, and 60 deg. of Altitude, and therefore from F, through these points, I draw the Lines F 10. F 20. F 30. F 40. F 50. and F 60. —— Then make A F in your *Trigon*, (*Figure XIV.*) equal to V N, in your Dial, which is the *Secant* of 35 deg. the Complement of the Plain's Reclination, and draw the Line A F perpendicular to F B.

Secondly, Out of your Dial-Plain Figure XIII, take V H the *Axis* of the *Horizon*, and put it into your *Trigon*, from A to B, and draw the Line A B, and that shall be the *Axis* of the *Horizon*.

Thirdly, Out of your Dial-Plain, (from the *Point* V) take the distances to the several Intersections that the obscure *Azimuth Lines* make with the *Horizontal Line*, at the *Points* 10, 20, 30, 40, 50 and 60 from H the *Azimuth* of the *Plain*, and set those distances into your *Trigon*, from A, upon the Line F B, drawing the Lines F B, F 10, F 20, F 30, F 40, F 50 and F 60. —— And now your *Trigon* being prepared, you may easily insert the *Circles* of *Altitude* into your Reclining Declining *Plains* as followeth.

Fourthly, To instance in the *Parallel* of 20 deg. of *Altitude* from the Intersection of the Line of 20 deg. of *Altitude* in the *Trigon* with the Line A B, take the distance to A, which distance set upon your *Dial-Plain* from V, upon the Line V H of your *Plain*, and it shall reach from V to *a*, so shall *a* be one *Point* upon the *Vertical Line* V H, through which the *Parallel* of 20 deg. of *Altitude* shall pass —— Also,

Take with your Compasses the distance from A, *to the Intersection of the* 20th. *Parallel of Altitude with the Line*	A 10	*And setting that distance from the Point* V, *upon the*	10th.	*Azimuth on both sides of the Line* V H, *it shall give the Points*	*b*	*b*
	A 20		20		*c*	*c*
	A 30		30		*d*	*d*
	A 40		40		*e* &	*e*
	A 50		50		*f*	*f*
	A 60		60		*g*	*g*
	A 70		70		*h*	*h*

Through

Through which Points, if you draw a Line with an even hand, so that it may make no Angles, the Line *h g f e d c b a b c d e f*, so drawn, shall be the *Parallel* of 20 deg. of *Altitude* upon the *Plain*: And in this manner may all the other *Parallels* of *Altitude* be inscribed into the *Plain*; As in Figure XIII. And

Of these *Circles* of *Altitude* inscribed upon a *West Reclining Plain*, where the *Azimuths* are put in according to the *Points* of the *Compass*, and the *Circles* or *Parallels* of *Altitude* according to the *Proportions* of *Shadows* to their heights, you have an Example in Figure XII.

CHAP. VIII.

Of the Domifying Circles, *commonly called the* Circles *of* Position, *and how to inscribe them upon all sorts of Plains.*

THese are Great Circles of the Sphere, and therefore (by the I. Affection) they will be streight Lines; Their situation in the Sphere, is at the common intersection of the *Meridian* with the *Horizon*, and are reckoned, according to the *Rational way of Regiomontanus* (as the *Astrologers* term it) from the *Meridian* downwards to the *Horizon*, at 30 and 60 deg. which with the *Meridian* and *Horizon* are the *Cuspis* of the Six *Celestial Houses* above the *Horizon*, so that these Circles being inscribed upon any Dial-plain, it may be known in which of the Twelve Houses the Sun at any time is, and in what part, how near or far off of the *Cuspis*. They are Great Circles (as I said before) and their manner of inscription is very easie

SECT. I. *Upon the Horizontal, direct East and West, and East and West Reclining Plains.*

I Bring all these sorts of Plains under one Head for this Reason, because in all these Plains they are Parallels, as the Hour-lines are in East, West and Polar Plains.

1. In *Horizontal Plains*, They are thus easily inscribed: For, if through the common intersections of the Hour-lines of VIII and X with the Equinoctial, you draw Lines parallel to the Meridian or Hour-line of XII, those Lines so drawn shall be the *Cuspis* of the XII and XI Houses,—— The Meridian is the *Cuspis* of the X House.—— And the two other Lines drawn parallel to the Meridian through the intersections of the Hour-lines of II and IV with the Equinoctial shall be the *Cuspis* of the IX and VIII Houses —— And lastly, the East and West parts of the Horizontal Line are the *Cuspis* of the First and Seventh House.

An Example of an Horizontal Dial with these Circles inscribed upon it, you have in the Tenth Tractate hereof, *Page* 226.

2. In East and West Plains, the Circles of Position will be Parallels to the Horizon, as in the Horizontal they were to the Meridian; And the

manner

Figure II. manner how to inscribe them into these Plains, is thus. Upon the Quadrant QEL Figure II. set 38 deg. 28 min. the Complement of the Latitude from E towards L, and laying a Ruler from Q to that point, it will cut the Horizontal Line of the Plain in *n*, so is Q *n* the Secant Complement of the Latitude, which must now be made a *Radius*, and so placed from the point E (the foot of the Perpendicular Stile) upon the Line EG extended, *viz.* to Q, that it may be perpendicular to the Equinoctial; so shall the Equinoctial be a Tangent Line thereto, and the Tangent of 30 deg. shall give the point *o*, and the Tangent of 60 deg. the point *p* upon the Equinoctial, through which points *o* and *p* two Lines being drawn parallel to the Horizon, they shall be the *Cuspis* of the XII and XI Houses: As in Figure II.

3. Upon East or West Recliners: In these Plains, the Perpendicular Stile being made the *Radius*, find the Secant Complement of the Stile's height, and make that a New *Radius*; So shall the Tangents of 30 and 60 degrees set upon the Equinoctial Circle give points, through which to draw the *Cuspis* of the Houses, which must be parallel to the Meridian or Horizontal Line of the Plain.

SECT. II. *Upon North and South Plains, both Direct and Declining, Upon all Direct North or South Reclining, and upon all North and South Declining Reclining Plains.*

ONE general Rule will serve for the inscription of these Circles into these several sorts of Plains, for here they meet in a Center, which Center is the Common Intersection of the Meridian and Horizontal Line upon the Dial, and the distance of the *Cuspis* being 30 and 60 deg. upon the Equinoctial, which are equal to the Equinoctial hour distances of 8 and 10, and of 2, and 4 a Clock from the Meridian, therefore you have no more to do, but to draw right Lines from the Common Intersection of the Meridian with the Horizon, through the Intersections of the Hour-lines of 2, 4, 8 and 10 a Clock with the Equinoctial, and those Lines so drawn shall be the *Domifying Circles* required. Examples whereof you have in several Figures belonging to this Tractate.

As in an Equinoctial Dial Figure IV, where the Pricked Lines shew the Cuspises of the XII, and XI Houses, the Meridian is the Cusp of the X. And the other two Pricked Lines the Cuspises of the IX and VIII Houses.

Also in a Direct South Plain in Figure V. represented by the Pricked Lines in that Figure.

Likewise, in a Declining Reclining Plain, Figure VII. And Lastly, In a South Declining Plain, Figure XI.

CHAP.

CHAP. IX.

Of the Meridians *of other* Countries, *and how to insert them into any Sun-Dial.*

IT is easie to insert the Meridian of any other Country into any Sun-dial made for any other Country, if first you know the difference of *Longitude* between the two Countries, in Time; and also, whether the Remote Country lie *Eastward* or *Westward* from the *Home Country*: For,

If the *Remote Country* lie { *Eastward* / *Westward* } of the *Home Country*, it is *Meridian* or *Noon-tide* { *sooner* / *later* } in the *Remote Country* than in the *Home Country*.

As for *Example*, Suppose that in a Sun-dial here at *London*, I would insert the Meridian or Noon-tide of *Constantinople*. By the Tables of the latest and best Geographers, the Meridian of *Constantinople* lies *Eastward* of the Meridian of *London*, 30 deg. 45 min. which converted into Time (by allowing 15 deg. to one hour, and 1 deg. to 4 minutes of time) is 2 hours and 15 min. that is 2 hours and a quarter. Wherefore, if you substract 2 hours 15 min. from 12 hours (because *Constantinople* lies *Eastward* of *London*) the Remainer will be 9 hours 45 min. or 3 quarters of an hour. Wherefore, if (upon any Dial here at *London*,) upon the Hour-line of 9 and 3 quarters, you write the Word (or make some mark for) *Constantinople*, the Shadow of the Stile of the Dial, when it shall fall upon that *Word* or *Mark*, you may conclude it to be *Meridian* or *Noon-tide* at *Constantinople* —— and knowing at what time with *Us* it will be Noon to *Them*, it is easily known what hour it is there at any time here.

For if it be at London		It is at Constantinople	
4	*in the Morning*	6 15	*Morning*
5		7 15	
6		8 15	
7		9 15	
8		10 15	
9		11 15	
10		12* 15	
11		1 15	*Afternoon.*
12 *		2 15	
1	*in the Afternoon*	3 15	
2		4 15	
3		5 15	
4		6 15	
5		7 15	
6		8 15	
7		9 15	
8		10 15	

In some of the Dials belonging to this Tractate you have several Countries inserted, especially in the Declining Reclining Dial, Figure VII.

And that the like may be done for other Countries, here followeth

A Table of *Longitudes*, or *Difference* of *Meridians* in *Time*, of ſeveral Eminent Places in the *World* from *London*.

Places lying East of London.	*Difference in Time.* H.	M.	*Places lying West of* London.	*Difference in Time.* H.	M.
Paris in *France*	0	10	*Edenborough* in *Scotland*	0	2
Amſterdam in *Holland*	0	21	*Madrid*	0	16
Copenhagen	0	49	*S. Helena Inſ.*	0	20
Stockholm	1	1	*Dublin*	0	26
Cape of *Good Hope*	1	5	*Tanger*	0	29
Rome in *Italy*	1	6	*Madera*	1	18
Venice	1	8	*Tenarif*	1	22
Dantzick	1	18	*Cape Farewel*	3	13
Cracovia	1	20	*C. Raze*	3	16
Conſtantinople	2	15	*Surinam*	3	42
Caro	2	16	*Barbadoes* west indies	3	53
Jeruſalem	2	30	*Bermudas*	4	14
Aleppo in *Spain*	2	40	*Boſton* in *New England*	4	40
Muſcow —Russia metro:	2	48	*New York*	4	58
Bagdat olim Babylon	3	14	*Port Royal*	5	4
Iſpahan persia metro:	3	46	*Jame's Town*	5	12
Surrat	5	6	*Careleton Inſ.*	5	18
Fort St. George	5	30	*Charle's Town*	5	44
Agra mogols empire	5	34	*Mexico*	6	47
Bantam in Java . . .	7	1	*New Mexico*	8	31
Peking	7	51	*P.* Sir *Francis Drake*	9	40
Nangeſagne	8	32			
Iedo	9	16			

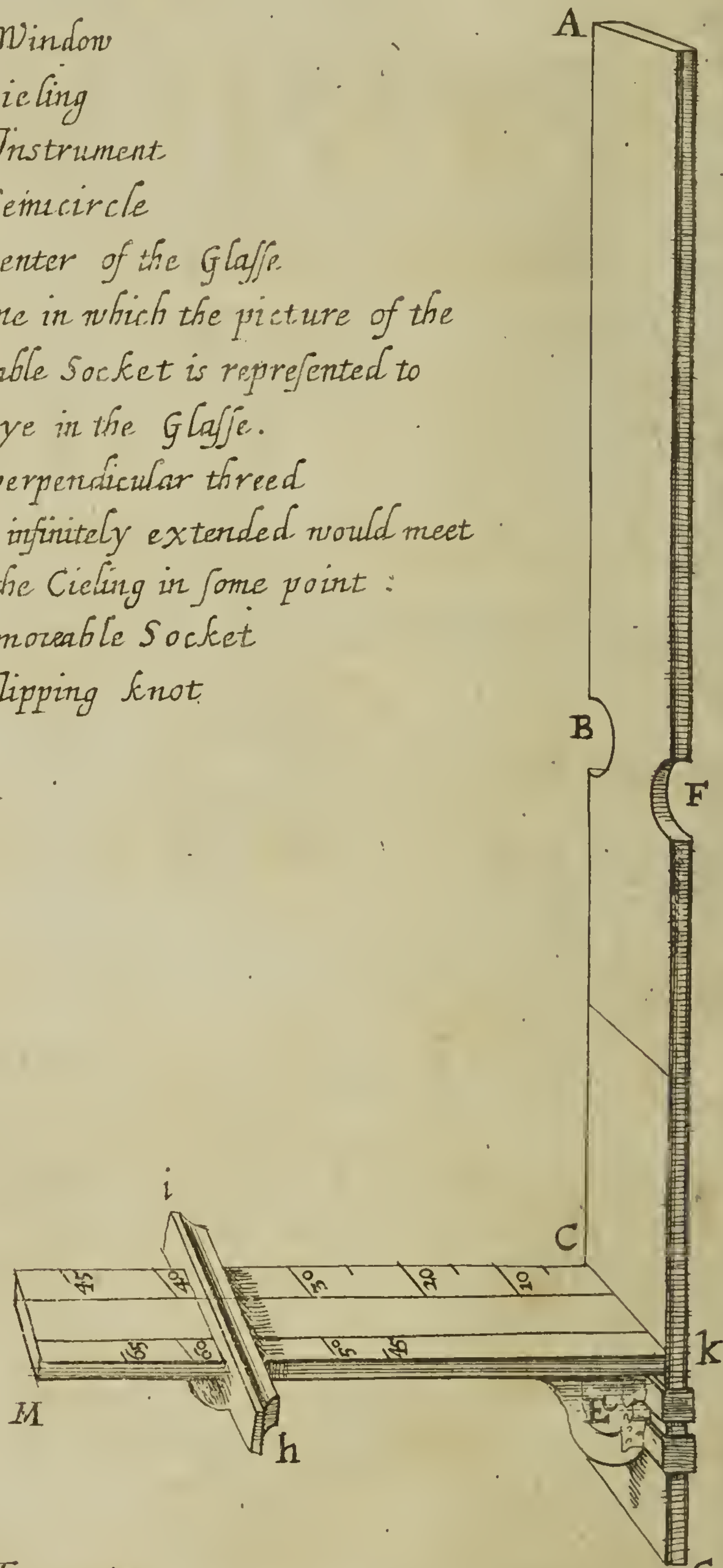
It may be now expected I ſhould here further ſhew how ſome other *Aſtronomical* and *Geographical Concluſions* might be inſerted into Sun-dials; As the *Signs Aſcending*, *Deſcending* and *Culminating*; The *Horizons* of other *Countries*, &c. But I do here purpoſely omit them, for that in the *Ninth Tractate* hereof, the manner how to inſcribe ſuch *Furniture*, not into Regular Plains only, but into Irregular alſo, as into Concave, Convex, or mixt of both, is treated of at large: And ſo I conclude this *TRACTATE*.

The End of the Fourth TRACTATE.

HOW

The Instrument

M.N . *the Window*
O : *the Cieling*
C.D . *the Instrument*
A.B . *the Semicircle*
H . *the Center of the Glasse*
H.I . *the line in which the picture of the moveable Socket is represented to the eye in the Glasse.*
K.L . *the perpendicular threed*
H.I . *being infinitely extended would meet with the Cieling in some point :*
F.G . *the moveable Socket*
I . *the slipping knot*



Against Page 143. Tractate 12.

HOW THE FURNITURE OF SUN-DIALS;

May be Inscribed upon all Sorts of PLAINS, by the SCALES of NATURAL TANGENTS and SECANTS.

The Fifth TRACTATE.

PROEME.

BY the *Scales of Chords*, and *Natural Tangents* and *Secants*, the *Ruler* mentioned in the First Tractate, *Page* 15. *Figure II.* All *FURNITURE* may be inscribed upon all sorts of *Plains*; but as they are there Graduated upon a Strait Ruler, they are only serviceable to that *Radius* to which the *Scales* are made. But being (as in the forementioned 15th. *Page* is intimated) put upon a *Sector*, with an opening Joynt, they will be applicable to any proposed *Radius*, as in the performance of almost, all the Work in this Tractate it will be required so to vary.

And further note, That if a Line of Equal Parts (which Mr. *Gunter*, deservedly, calls the *Line* of *Lines*) be also put upon such a Joynt-Ruler it will, by the help of the *Tables* of *Natural Tangents* and *Secants* (brief ones whereof follow in the next *Tractate*) supply the use of the forementioned *Scales*, and in many Cases much better, especially when the *Tangents* or *Secants* of many degrees (as above 70, *&c.*) are required to be laid down upon any Line. I thought good to give intimation hereof in this place, because of the frequent use that will be made of these *Lines* or *Scales* for many purposes hereafter signified.

CHAP.

CHAP. I.

Of Proportioning of the Stile to the Plain.

FOrasmuch as by the Eighth *Affection*, Chapter I. of the foregoing Tractate, it is not the whole *Stile* or *Axis* of the *Dial* that gives the *Shadow* to these *Parallels*, *Azimuths*, *&c.* But some one *Point* therein assigned; good consideration therefore ought to be taken, that that *Point* be so chosen, that it may continue casting its *Shadow* upon the *Dial-plain*, as long as conveniently may be, and not taken at so large a distance from the *Center* of the *Dial*, as to cast its Shadow off of the *Plain*, so that the *Lines* drawn thereon, will be of no use, the *Apex* which should point to them, being remote from them, and casting its *Shadow* upon some other *Object* besides the *Plain*.—— On the contrary, This *Point* ought not to be chosen so near the *Center* of the *Dial*; so that the *Lines* or *Sections* drawn upon the *Dial* shall run so near (or be crowded) together, that at any competent *distance* of place they cannot be discovered. Therefore, that this *Point* may be *judicially chosen*, observe these following *Directions*.

1. If your *Plain* be small, consider whether it be *Direct*, or *Declining*, and if *Declining*, whether *much* or *little* from the *South* or *North* Points.

2. If the *Plain* be *Direct*, the *Substile* may best be placed in the *middle* of the *Plain*; But if it do *decline*, then let the *Substile* be set on that *Side* or *part* which is *opposite* to the *Coast* of its *Declination*, *i. e.*

If the *Plain* decline $\left\{ \begin{array}{l} \textit{Eastward} \\ \textit{Westward} \end{array} \right\}$ set the *Substile* more on the $\left\{ \begin{array}{l} \textit{West} \\ \textit{East} \end{array} \right\}$ Side of the *Meridian*.

3. The *Substile* well placed, and room left about the Edges of the *Dial-plain* for the *Figures* belonging to the *Hour-lines* to stand, divide the remaining part of the *Plain* (from the *Center* to the lower *Margin*) into two parts; so, as that part next the *Center* of the *Dial*, may be the *Tangent* of the *Complement* of the *height* of the *Stile* above the *Plain*, (or of the new *Latitude*, as by *Affection VI. Chap. I.* of the *Fourth Tractate* beforegoing.) And the other part, the *Tangent Complement* of the *Sun's Meridian Altitude*, in the beginning of that *Tropick* which is *remotest* from the *Center* of the *Dial*.—— Now the *Radius* (or *Tangent* of 45 deg.) which is proper to these *Tangents*, shall be the length of the *Perpendicular Stile*, and is to be placed in the Point of *Division* in the *Substile*, and must stand *Perpendicular* thereunto.

CHAP. II.

Of the inscribing of the Parallels *of the* Sun's Course *in the beginning of each* Sign *of the* Zodiack; *or of the* Parallels *of the* Sun's Course *when the* Day *is either just* 8, 9, 10, 11, 12, 13, 14, 15 *or* 16 hours *long.*

A *Sign* is the Twelfth part of the *Zodiack*, and so contains just 30 deg. and so the Sun passing about one of these degrees in a Day, the distance between the beginning of the *Sun*'s entrance into one *Sign*, and his continuance therein to his entrance into the next, is about 30 days.

A

A *Parallel* (according to the general acceptation) is the Sun's *Diurnal motion* day by day; and forasmuch as there are 47 deg. between the *Tropicks*, there may be described, upon a large *Dial-plain* so many *Parallels*. But although there are 47 of these *Parallels*, yet in this our *Latitude* of *London*, being 51 deg. 30 min. we do usually account (or make use of in *Sun-Dials*) only *Nine*, and those are they which do make the *Day* from the *Sun's Rising* to his *Setting* to be *just*, and *equally*, either 8, 9, 10, 11, 12, 13, 14, 15 or 16 *hours* long.

The description of these *Parallels* of the *Sun's Course* (or *Diurnal Arches*) and of the *Sun*'s entrance into any of the *Signs* of the *Zodiack*, is effected by the same Artifice; and for the effecting hereof, due respect must be had to the *Sun's* place in the *Zodiack*, and what *Altitude* he shall have at all hours, when he enters into such a *Sign* of the *Zodiack*, or when his *Diurnal Arch* shall be either, 8, 9, 10, 11, *&c. hours* long.

Now if you would inscribe the *Parallels* of the *Sun's Course* at his entrance into each of the 12 *Signs*, you must first prepare a Table of the *Sun's Altitude* at all *hours* of the *Day* (and of halves and quarters also if you will) And such a *Table* I have here inserted, the making whereof, with several other of the like nature shall be shewed in the *Ensuing Tractate*.

A Table *shewing what* Altitude *the* Sun *shall have at his Entrance into any of the* 12 Signs, *at all* Hours *of the* Day, *In the* Meridian *or* Latitude *of* London, 51 *deg.* 30 *min.*

Hours		*Cancer*		*Leo* or *Gemini*		*Virgo* or *Taurus*		*Libra* or *Aries*		*Scorpio* or *Pisces*		*Sagittar.* or *Aquarius*		*Capric.*	
		d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.
12		62	0	58	42	50	0	38	30	27	1	18	18	15	0
11	1	59	43	56	34	48	12	36	58	25	40	17	6	13	52
10	2	53	45	50	55	43	12	32	37	21	51	13	38	10	30
9	3	45	42	43	6	36	0	26	7	15	58	8	12	5	15
8	4	36	41	34	13	27	31	18	8	8	33	1	15		
7	5	27	17	24	56	18	18	9	17	0	6				
6		18	11	15	40	9	0	0	0						
5	7	9	32	6	50										
4	8	1	32												

This *Table* being thus *Collected*, you are to note, that in all direct *Horizontals*, the *Perpendicular Stile* being made *Radius* (or the *Tangent* of 45 deg.) the *Tangent Complement* of the *Sun's height*, (in any *Sign* of the *Zodiack*, or in any *Parallel* of the *Day's length*) at any hour of the day, being set off from the foot of the *Perpendicular Stile*, upon its respective *Hour-line*, will give a *Point*, upon that *Hour-line*, through which that *Parallel* (whether of the *Signs* of the *Day's length*) shall pass. And this Work must be repeated so often as are the number of *Parallels* to be inserted, and the *Hour-lines* do require; and thus doing, you shall have *Points* enough in each *Hour* to draw any *Parallel* by.

As thus for *EXAMPLE*: Let it be required to find *Points* in the respective

ſpective *Hour-lines*, through which the *Parallel* of the *Sun's Courſe*, at his entrance into either of theſe *Signs*, *Scorpio* or *Piſces* ſhall paſs. —— Repair to the former *Table*, where you ſhall find, that the *Sun* being in the beginning of either of thoſe *Signs*, *Scorpio* or *Piſces*,

His Altitude at		Of the Clock to be	d.	m.	Whoſe Complement is	d.	m.
12			27	01		62	59
1	Or 11		25	40		64	20
2	Or 10		21	51		68	9
3	Or 9		15	58		74	2
4	Or 8		8	33		81	27
5	Or 7		0	6		89	54

Then having a *Sector*, take in your Compaſſes the length of the *Perpendicular Stile* of your *Dial*, and to that diſtance open the *Sector* in 45 deg. of the *Tangents*, and the *Sector* ſo reſting, take 62 deg. 59 min. therefrom (which is the *Tangent Complement* of 27 deg. 1 min. the *Sun's Altitude* at 12 a Clock) and ſet that diſtance from the foot of the *Perpendicular Stile* upon the Line of 12, and that ſhall be the *Point* there, through which the *Parallel* of *Scorpio* and *Piſces* ſhall paſs. —— Alſo take from the *Sector* the *Tangent* of 64 deg. 20 min. (the *Complement* of 25 deg. 40 min. the *Altitude* at 1 or 11 a Clock) and ſet that diſtance from the foot of the *Perpendicular Stile* upon the *Hour-lines* of 11 and 1 a Clock, and thoſe ſhall be the *Points* through which your *Parallel* is to paſs.

Take likewiſe the Tangent *of*	d.	m.	*And ſet them from the foot of the* Perpendicular Stile *upon the* Hour-lines *of*		*and*	
	68	9		2	*and*	10
	74	2		3		9
	81	27		4		8
	89	54		5		7

So they ſhall give *Points* upon each reſpective *Hour-line*, through which the *Parallel* of *Scorpio* and *Piſces* muſt paſs: And a *Line* traced with an *even hand* through thoſe Points ſhall be the *Parallel* of the *Sun's Courſe* at ſuch time as he enters *Scorpio* or *Piſces*: and the *Apex* or *Top* of the *Perpendicular Stile* ſhall, at that time of the year, by *his Shadow* exactly traverſe this *Line* or *Section*. And in the ſame manner, as the *Points* for this *Parallel* were found, and its *Line* drawn, ſo muſt all the reſt be drawn alſo.

Now generally, in *Vertical Dials Declining*, as alſo in ſuch as *Recline* alſo, that is to ſay, upon all *Plains* whatſoever, (as is intimated in the Sixth *Affection* aforegoing) draw an *Horizontal Dial* proper for the *Plain*, and inſcribe the *Signs* or the *Parallels* of the *Length of the day* upon it, according as is before directed, by ſetting off the *Tangent Complements* of the *Sun's Altitude* from the foot of the *Perpendicular Stile*, upon the *Hour-lines* (the *Perpendicular Stile* being always made *Radius*) and at the ends of theſe *Tangents* ſo ſet off upon every reſpective *Hour-line*, will be a *Point*, by which *Points*, *Lines drawn* with an even hand ſhall be the *Parallels* deſired. This *Horizontal Dial* being drawn in *obſcure* or *occult* Lines, when the Work is done may be expunged, and the true *Hour-lines* belonging to the *Plain*, as alſo the *Parallels* of the *Sun's Courſe* before found, may only remain, for they will be the ſame, as if they had been *drawn* from the *proper Hour-lines* belonging to the *Plain*.

Note, In the following Tractate there are Tables Calculated for the ready deſcribing of obſcure *Horizontal Dials* upon all Plains, and alſo Tables of the

the *Sun's Altitude* at all hours (in diverse Latitudes.) And an Example of an Horizontal Dial with the Tropicks of *Cancer* and *Capricorn* you have in the *Ninth Tractate*, *Page* 220 —— Also you have an Example of an Erect Direct East Dial, with the Parallels of all the 12 Signs upon it, in *Chap*. 2. *Pag*. 115 and 118. *Figure II.* of the *Fourth Tractate*; And two other Examples of Plains with the Parallels of the length of the day upon them; One is a Polar Dial, *Figure I.* the other is a South Dial, *Figure IX.* of the *Fourth Tractate*.

CHAP. III.

Of inscribing the Vertical Circles, (*commonly called* Azimuths) *upon all sorts of* Plains.

A *Zimuths* are great *Circles* of the *Sphere*, whose *Poles* lie in the *Horizon*, and do intersect each other in the *Zenith* and *Nadir* Points of the *Heavens* —— The whole *Horizon* is divided by *Mariners* into 32 equal Parts or Points, which they call *Winds* or *Points of the Compass* and denominate them by *North*, *N by W. N N W. &c.* every *Point* containing 11 degrees and a quarter —— This is their way of accounting, but the *Account* used by *Astronomers* and *Geographers* is more natural, and that is by 10, 20, 30, 40 degrees, *&c.* to 90 deg. from the *Meridian*, both ways, towards the *East* and *West*.

How to inscribe these into Dial-Plains.

SECT. I. *In* Horizontal *Dials.*

THese *Plains* lying parallel to the *Horizon*, and these *Azimuths* being *Great Circles*, they (by the 1. *Affection*) being *Projected* upon such *Plains* become *Streight Lines*, and (by the 2. *Affection*) because these *Plains* lie *Perpendicular* to these *Circles*, in the *Heavens*, these *Lines* projected, shall all meet in a *Center* at equal Angles (which *Center* is the foot of the *perpendicular Stile.*) —— Wherefore, making the foot of the *perpendicular Stile* the *Center*, describe thereon a *Circle* upon the *Dial-Plain*, and thereon set off (both ways) from the *Meridian* such *Arches*, either 11 degrees and a quarter for *Points of the Compass*, or 10, 20, 30, 40, *&c.* degrees for the *Astronomical Account* upon the *Horizon*; Through these *Divisions*, *right Lines* being drawn from the foot of the *perpendicular Stile* shall represent these *Azimuths* upon the *Plain*.

An Example of an Horizontal Dial with the Azimuths upon it according to the Mariner's Account by Points of the Compass, you have in the Ninth Tractate following, *Page* 220.

SECT. II. *In Upright South or North Dials.*

THese *Plains* lying *Parallel* to the *Vertical Circles* in the *Heavens*, are (by the 2. *Affection*) *right Lines*, *parallel* one to the other. And to inscribe them into these *Plains*, you must —— Through the *Foot* of the *perpendicular Stile*, draw a Line Parallel to the *Horizon*, and making the *perpendicular Stile* a *Radius* (or *Tangent* of 45 deg.) Upon this *Line* from the *Meridian* (on both sides) set off the *Tangents* of 11 deg. and a quarter, 22 deg. and a half, *&c.* for

for *Points of the Compaſs*, or the *Tangents* of 10, 20, 30 deg. *&c.* which beſt liketh you,—— Now, if through theſe *points* you draw *right Lines perpendicular* to the *Horizontal Line* they will be all of them *parallel* one to another, and alſo *parallel* to the *Meridian* or 12 a Clock Line of the Dial, but at *unequal diſtances* one from another, according as the *Tangent Line* increaſes; And theſe *Lines* thus drawn, ſhall be the *Azimuth Lines* proper to thoſe *Plains.*

An Example of a Direct South Dial with Azimuths drawn upon it, you have in Figure V. and a Direct Eaſt Dial with Azimuths you have in Figure II. of the Fourth Tractate.

SECT. III. *In* Vertical (*or* Upright) Declining Plains.

THE *Azimuth Lines* here are alſo *parallel* one to another, and muſt be inſerted in all reſpects as in the former *Plains*, from the *Meridian* of the *Plain* (if you will) or from the *Meridian* of the *Place*, but then, juſt allowance muſt be made for the *Difference of Meridians*, or (which is all one) for the *Difference of Longitude* between the *Meridian of the Plain* and the *Meridian of the Place.*

An Example of a South Declining Plain, with Azimuths drawn upon it you have in Figure IX. of the Fourth Tractate.

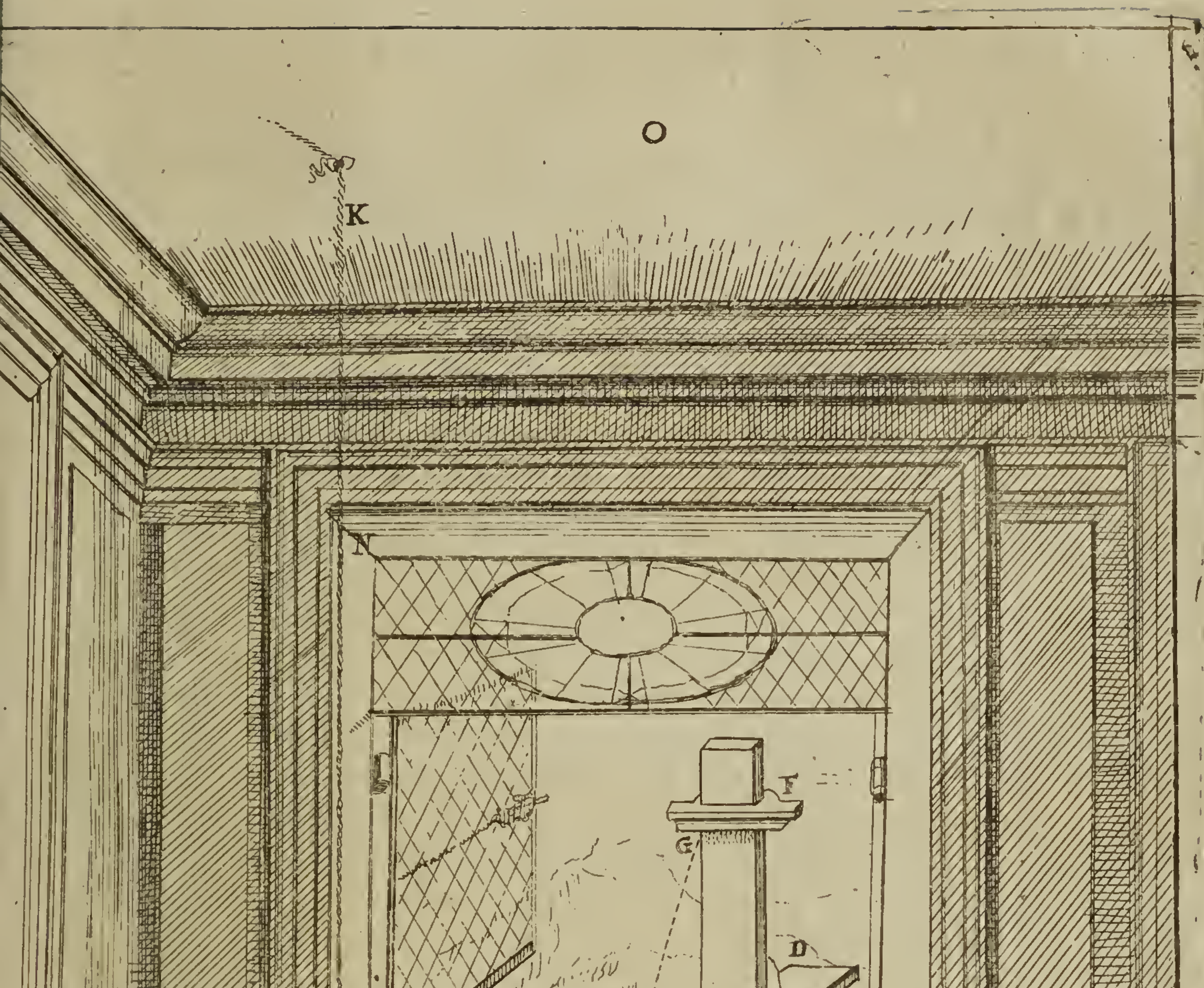
SECT. IV. *In* Declining Reclining Plains.

THE *Perpendicular Stile* being choſen, and made the *Radius* (or *Tangent* of 45 deg.) Take the *Tangent Complement* of the Plain's *Reclination*, and ſet it from the foot of the *perpendicular Stile*, to the *Meridian* of the *Place*, which *point* ſhall determine the *Zenith* of the *Place* upon the *Plain*, through which *point*, and the *Foot* of the *perpendicular Stile* (which is the *Zenith* of the *Plain*,) a *right Line* drawn ſhall be *perpendicular* to the *Horizontal Line*, and ſhall (when drawn) concur with the *Equator* in the *Hour-line* of *Six* (if you have not committed ſome former error.) —— Now therefore, if from the *Foot* of the *perpendicular Stile*, upon this *Perpendicular*, you ſet off the *Tangent* of the *Plain's Reclination*, a Line drawn from the end thereof at *Right Angles* unto it, that *Line* (ſo drawn) ſhall be the *Horizontal Line*, upon which *Line*, the Tangents of 11 and a Quarter, 22 and a half, *&c.* for *Points of the Compaſs*, or of 10, 20, 30, *&c. degrees* (the *Secant* of the *Plain's Reclination* being now made *Radius*) being ſet from the ſaid *right Angle*, Lines drawn from them to the *Zenith* of the *Place*, ſhall be the *Azimuths* required, —— And becauſe theſe *Declining Reclining Plains* do lie *obliquely* to the *Azimuth* or *Vertical Circles* in the *Heavens*, therefore (by the former 2. *Affection*) though they be *Strait Lines*, and do meet in *one Center*, namely in the *Zenith* of the *Plain*, yet do they meet at *unequal Angles.*

The Examples in the Fourth Tractate of Reclining Plains with Azimuths deſcribed upon them are —— (1.) A Polar Plain, Figure I. —— (2.) An Eaſt Reclining Plain, Figure XII. —— And (3.) A Declining Reclining Plain, Figure XIII.

Note here, That if the diſtance between the *Meridians* be known upon the *Horizontal Line*, the *Azimuths* which were accounted from the *Meridian of the Plain*, may be fitted to Account as from the *Meridian* of the *Place*, with eaſe. —— For, Let the diſtance be the Tangent of the 20 deg. then that *Azimuth* which is 10 deg. from the *one*, is 10 deg. from the

other



Against Page 148 in Tractate 12

other alſo; And that which is 30 deg. on the ſame ſide of the *Subſtile* is 10 deg. on the *other* ſide of the *Meridian of the Place.* The like is to be obſerved for any other diſtance.

CHAP. IV.

Of inſcribing of the Almicanthar, *(commonly called* Circles *or* Parallels, *of the* Sun's Altitude) *upon all ſorts of* Plains.

A *Lmicanthers* or *Circles* of *Altitude*, are *leſſer Circles of the Sphere*, and therefore (by the 3. *Affection)* being deſcribed upon any *Plain* which lies not parallel to the *Horizon* of the *Place* become *Conick Sections*—— Theſe *Almicanthers* may not improperly be called *Parallels* of *Declination* from the *Horizon*, they having in all reſpects the ſame *Habitude*, *Relation* or *Affection* to the *Horizon*, which the *Parallels* of the *Signs* or of the *Sun's Courſe* have to the *Equinoctial*, to which they are *Parallel*. And therefore (as in the deſcribing of the *Signs* or *Parallels* of the *day's length)* An *Horizontal Dial* proper for the *Plain*, being firſt (obſcurely) delineated, as was *(*in the II. Section*)* ſhewed, that the Points through which the *Signs* or *Parallels* ſhould paſs upon every *hour*, might be obtained by applying the *Tangents* of the *Complements* of the *Sun's height* at thoſe *hours* in thoſe *Parallels*, from the foot of the *Perpendicular Stile* upon the reſpective *hours* to which thoſe *Altitudes* did belong.

Now to find what *Altitude* the *Sun* ſhall have he being upon any *Azimuth*, ſhall be hereafter taught in the enſuing Tractate, where ſeveral Tables thereof are Calculated for divers Latitudes; Notwithſtanding, I will here inſert

A Table *ſhewing what* Altitude *the* Sun *ſhall have in the beginning of each* Sign, *upon every* Tenth Azimuth.

Azimuth	*Cancer*		*Gemini* or *Leo*		*Taurus* or *Virgo*		*Aries* or *Libra*		*Piſces* or *Scorpio*		*Aquar.* or *Sagitt.*		*Capric:*	
	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.
South	62	0	58	42	50	0	38	30	27	0	18	18	15	0
10	61	43	58	24	49	38	38	4	26	30	17	45	14	25
20	60	51	57	28	48	33	36	46	25	9	16	5	12	41
30	59	52	55	52	46	40	34	34	22	27	13	15	9	45
40	57	20	53	29	43	55	31	21	18	48	9	14	5	34
50	54	3	50	12	40	11	27	5	13	58	3	57	0	6
60	49	50	45	53	35	23	21	41	8	0				
70	44	40	40	25	29	27	15	13	1	0				
80	38	11	33	46	21	29	7	52						
Ea. or W.	30	38	26	10	14	25	0	0						
100	22	27	18	2	6	45								
110	14	14	9	58										
120	6	34	2	30										

Your *Table* being thus prepared, and your *Dial* obscurely drawn, You are to make use of that *Azimuth* which is perpendicular to your *Plain* (which in all *Plains* is that which passeth through the *Foot* of the *Perpendicular Stile*) but all the other *Azimuths* also being inscribed obscurely, the *Tangent's Complement* of the *Sun's height* above the *Plain*, when he is in any *Azimuth*, applied from the foot of the *Perpendicular Stile*, upon the respective *Azimuth* gives a *Point*, through which that *Almicanthar* or *Circle of Altitude* upon that *Azimuth* must pass.

An Example of an Horizontal Dial with the Almicanters or Circles of Altitude, (as they are proportioned to the height of Perpendicular Objects to their heights) you have in the Ninth Tractate, *Page* 220. And another (*viz.* an East Reclining Plain) with the like Circles of Altitude upon it you have in Figure XII. of the Fourth Tractate; And upon a South Declining Plain in Figure XI. of the Fourth Tractate; And lastly, upon a Declining Reclining Plain in Figure XIII. of the same Fourth Tractate.

CHAP. V.

Of the Babylonish, Italian *and* Jewish hours, *and how to describe them upon* Sun-Dials.

I Do couch these three under one *Head* or *Table*, for that the manner of their Inscription into *Sun-Dials* is much after the same manner, and being they are *Hour-lines*, so *Great Circles*, and therefore, being described upon a *Plain*, they become by (the first *Affection*) *Strait Lines*.

SECT. I. *For the* Babylonish hours.

THE *Babylonish hours* are accounted the equal hours from the *Sun's Rising*, for at what time soever, at all times of the year, the Sun appears or rises, above the *Horizon*, that is the first minute of their day. These *Hour-lines* may be inscribed upon any *Plain* by help of those two *Parallels*, which do shew the *Longest* and *Shortest Days*, consisting of equal or entire hours in length in any *Latitude*, as here in the *Latitude* of *London* 51 deg. 32 min. the *shortest* day consisting of *Equal hours* is that day that is just 8 hours long, and the *Longest Day* in that *Latitude* is that which is just 16 hours long. By help of the Parallels of the *Sun's Course* for these two days, and the *Equinoctial*, all the *Babylonish hours* may be drawn upon any *Plain* in manner following.

Hours from Sun Rising, for Babylonish *hours*	*Length of the Day* 8 *hours*	12 *hours*	16 *hours*		*Hours from Sun Setting, for* Italian *hours.*
1	9	7	5	13	1
2	10	8	6	14	2
3	11	9	7	15	3
4	12	10	8	16	4
5	1	11	9	17	5
6	2	12	10	18	6
7	3	1	11	19	7
8	4	2	12	20	8
9	5	3	1	21	9
10	6	4	2	22	10
11	7	5	3	23	11

It is evident, in this *Latitude*, that when the day is 8 hours long, the Sun rises at 8 of the Clock in the Morning, then at 9 a Clock the Sun hath been up *One* hour —— When the day is 12 hours long, the Sun rises at 6, and at 7 a Clock it hath been up just *One* hour —— When the day is 16 hours long, the Sun rises at 4 of the Clock, and at 5 it hath been up *One* hour, Wherefore to draw the *Babylonish hours* observe this Table

Table —— If you draw a ſtrait Line through the hour 9 in the Parallel of 8 hours, through the hour 7 in the Parallel of 12 hours, and through 5 in the Parallel of 16 hours, that right Line (for ſo it will prove to be, if you have committed no former error in the reſt of your work) ſhall be the *Firſt Babyloniſh hour.* Again,

$$\textit{A Line drawn through the hour of}\left\{\begin{array}{c}10\\8\\6\end{array}\right\}\textit{In the Parallel of}\left\{\begin{array}{c}8\\12\\16\end{array}\right\}\textit{Shall be the}\text{ Second Babyloniſh hour.}$$

And ſo of all the reſt as in the Table above.

Note, That in *Winter* time, when the *Parallel* of 8 hours ſhall fail, the other two Points of 5 in the *Parallel* of 12 and of 3 in the *Parallel* of 16 will ſerve to draw the ſeventh hour from Sun *Riſing*, becauſe they be ſtrait Lines. And after Six hours are drawn, you ſhall find the *Equinoctial* (or *Parallel* of 12 hours) will fail you, wherefore, ſome other *Diurnal Arch*, as of 9 or 10 hours, muſt be inſerted to ſupply that defect.

SECT. II. *For the* Italian Hours.

THE *Italian hours* are accounted from the preceding *Sun Setting*, and are numbred by 1, 2, 3, 4, *&c.* from *Sun Setting* —— To inſcribe theſe hours, the ſame two *Parallels* of 8 and 16 hours, as alſo the *Equinoctial* or *Parallel* of 12 hours will ſerve to inſcribe them, and alſo the ſame Points in the ſame Parallels, and the former Table will ſhew you through what 3 Points each hour is to be drawn —— For a right Line drawn

$$\textit{Through}\left\{\begin{array}{c}5\\7\\9\end{array}\right\}\textit{In the Morning, in the Parallel of}\left\{\begin{array}{c}16\\12\\8\end{array}\right\}\textit{Shall be the hour of One,}$$

Likewiſe, (obſerving the ſame order as before)

$$\textit{Through}\left\{\begin{array}{c}3\\5\\7\end{array}\right\}\textit{In the Afternoon, in the Parallel of}\left\{\begin{array}{c}16\\12\\8\end{array}\right\}\textit{Shall be the 23d hour.}$$

The *Night hours* 9, 10, 11, *&c.* are the *Morning hours* produced.

An Example of a Direct South Dial, with both the *Babyloniſh* and *Italian* hours upon it you have in Figure X. of the Fourth Tractate. And alſo ſome of the ſame upon a Polar Dial, Figure I. and all of them upon an Equinoctial Dial, Figure IV. of the Fourth Tractate.

SECT. III. *For the* Jewiſh Hours.

IT was the Cuſtom of the *Ancient Jews* to divide their *Day*, as alſo their *Night (*whether *long* or *ſhort)* into 12 equal parts; beginning their *Day* at *Sun Riſing*, and their *Night* at the *Sun's Setting*, ſo that our 12 of the Clock at *Noon*, was always their *Sixth hour* of the *Day*, and our 12 at *Night* was always their *Sixth hour* of the *Night*, and according to this Diviſion were their *Dials* made; So that all *Summer* long, when the Sun is in *Northern Signs*, the *Jewiſh hours* of the *Day* are longer than their *hours* of the *Night*; and all the *Winter*, while

while the Sun is in the Six *Southern Signs*, the *hours* of their *Night* are *longer* than the *hours* of their *Day*; But when the *Sun* is in the *Equinoctial*, the *hours* of their *Day* and *Night* are *Equal*, and the ſame with all other Nations.

The manner of inſcribing theſe *Hour-lines* into *Sun-Dials* is not much different from the inſcribing of the *Babyloniſh* and *Italian* hours.

Wherefore, having drawn the true *Hour-lines* upon your *Plain*, with the *Half hours*, and *Quarters* (which in this caſe is neceſſary to be done) deſcribe thereupon alſo the *Two Tropicks*, and the *Equinoctial*; Which being drawn, Make choice of two *Parallels* of the length of the day, which muſt be either of them equidiſtant from the *Equinoctial* on either Side thereof, which let be the *Parallels* of 9 hours, and 15 hours, one being 3 hours *leſs* than 12 hours, and the other 3 hours *more* than 12. Inſcribe (obſcurely) upon your *Plain* theſe two *Parallels* of 9 and 15 hours (they being the moſt convenient for this purpoſe) becauſe the *Jewiſh hours* will fall (in theſe two *Parallels*) juſtly upon the *hours, halves* and *Quarters* of the *common Hour-lines*, and ſo will the *Jewiſh hours* (by that means) be the eaſier drawn. Now the *Points* through which every one of the *Jewiſh hours* muſt paſs, this little *Table* plainly ſheweth, wherein you may ſee, that the Firſt *Jewiſh hour* muſt be drawn through 5 hours 45 min. (or 5 hours 3 quarters) in the parallel of 15 hours, through 7 hours in the *Equinoctial*, and through 8 hours 15 min. (or 8 hours and a quarter) in the Parallel of 9 hours; This Line thus drawn through theſe 3 Points, ſhall be the *First Jewiſh hour*.

Jewiſh hours.	*The Parallel of* 15 *hours.* H	M	Equinoctial.	*The Parallel of* 9 *hours.* H	M
1	5	45	7	8	15
2	7	0	8	9	0
3	8	15	9	9	45
4	9	30	10	10	30
5	10	45	11	11	15
6	12	0	12	12	0
7	1	15	1	0	45
8	2	30	2	1	30
9	3	45	3	2	15
10	5	0	4	3	0
11	6	15	5	3	45
12	7	30	6	4	30

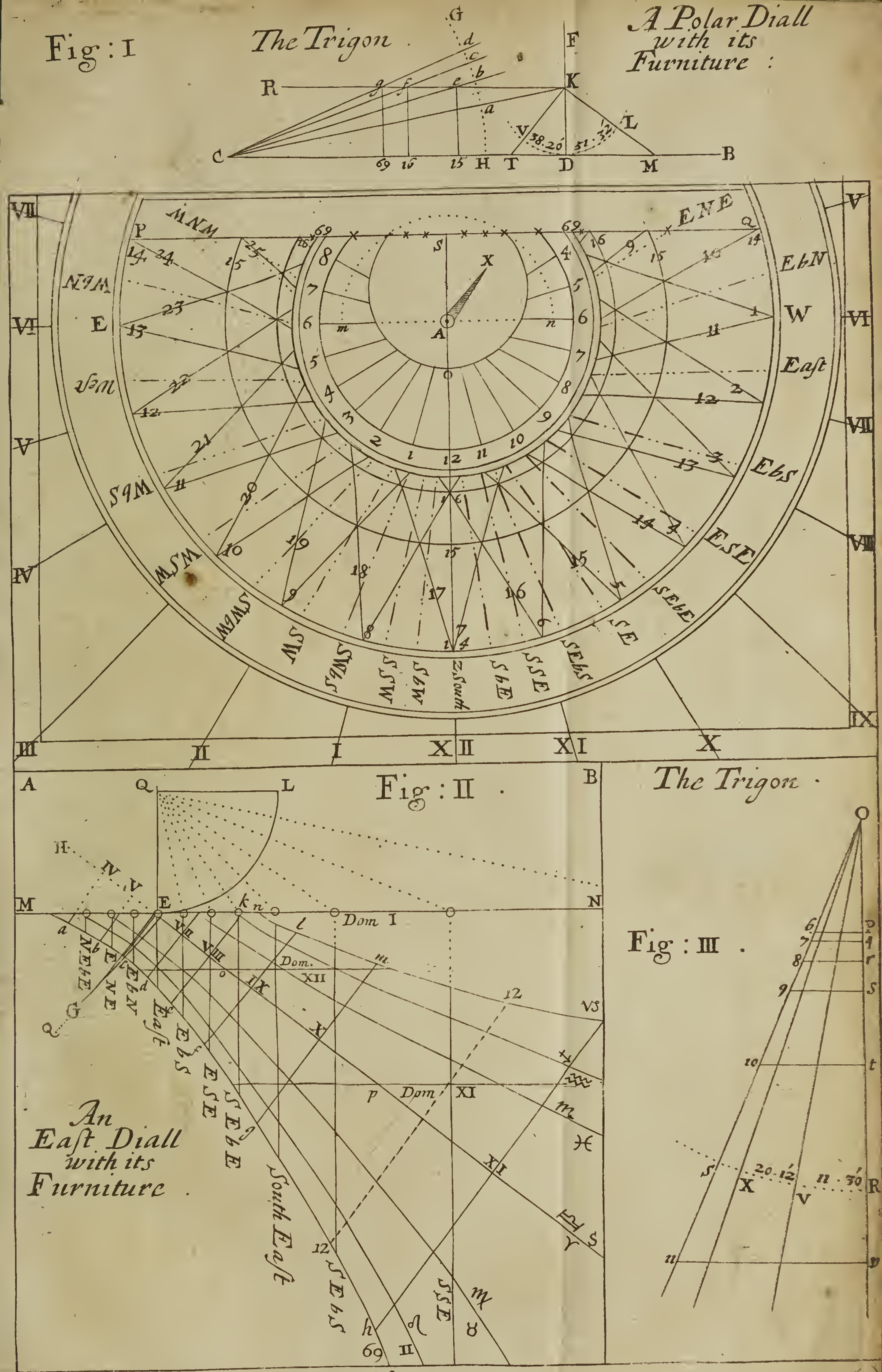
In like manner, a Line drawn through

h.	*m.*		*h.*	
7	0		15	
8	0	*In the Parallel of*	12	*Shall be the* Second Jewiſh hour.
9	0		9	

And ſo all the reſt, as in the *Table*. Our 12 a *Clock* being their *Six a Clock*, and the reſt in order from *Sun Riſing* to the *Sun's Setting*.

An Example of an Upright Declining Plain, with the Old Unequal or *Jewiſh* hours upon it, as alſo of all the Parallels of the day's length at equal hours, you have in Figure IX. of the Fourth Tractate.

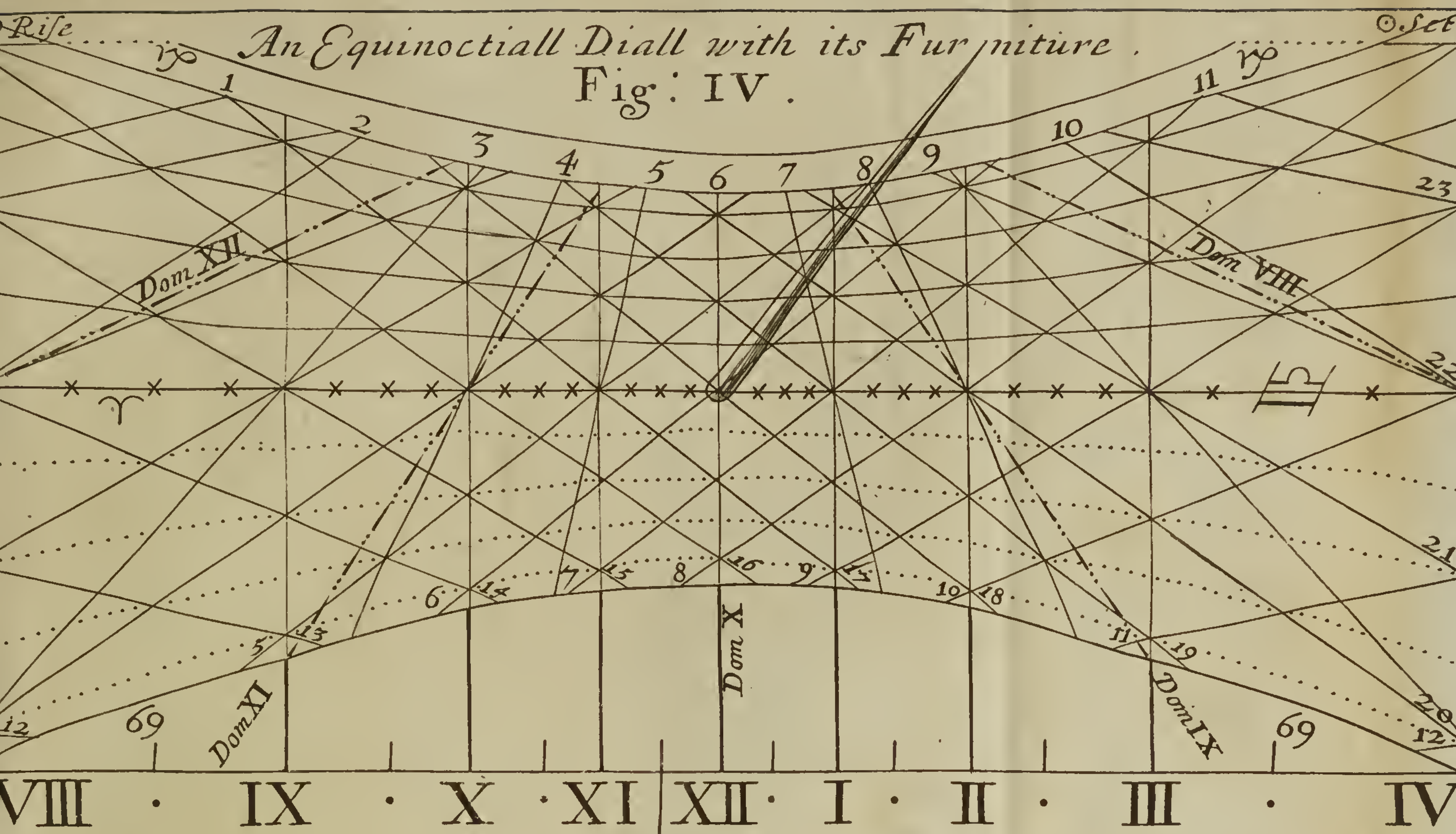
The End of the Fifth TRACTATE.



At the End of the Fifth Tractate

An Equinoctiall Diall with its Furniture.

Fig: IV.



A Direct South Diall with its Furniture.

Fig: V.

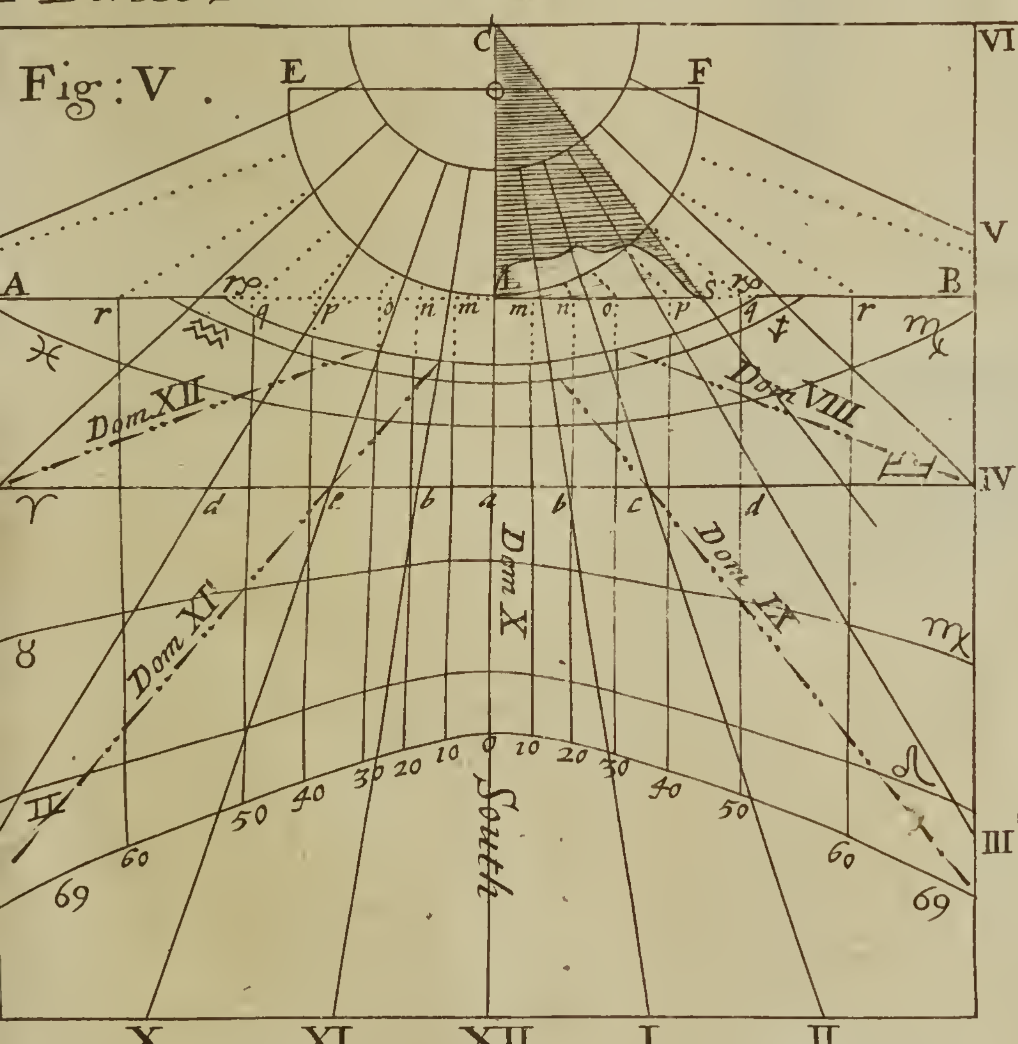
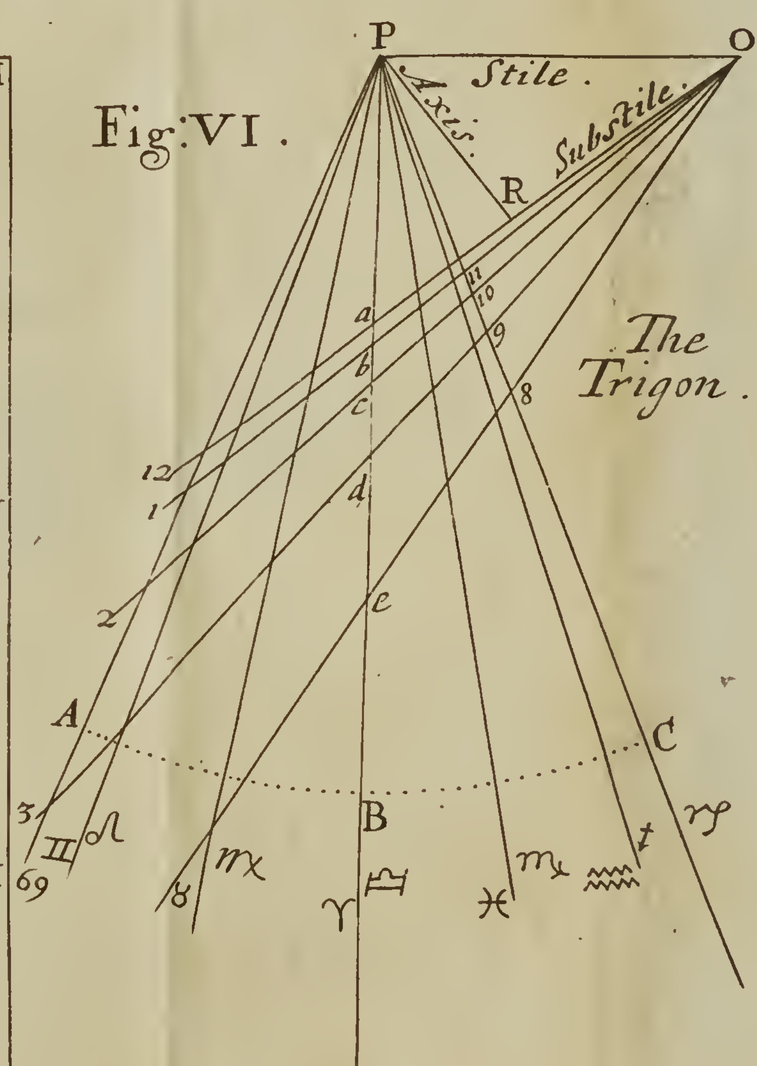


Fig: VI.



(2)

Fig VII

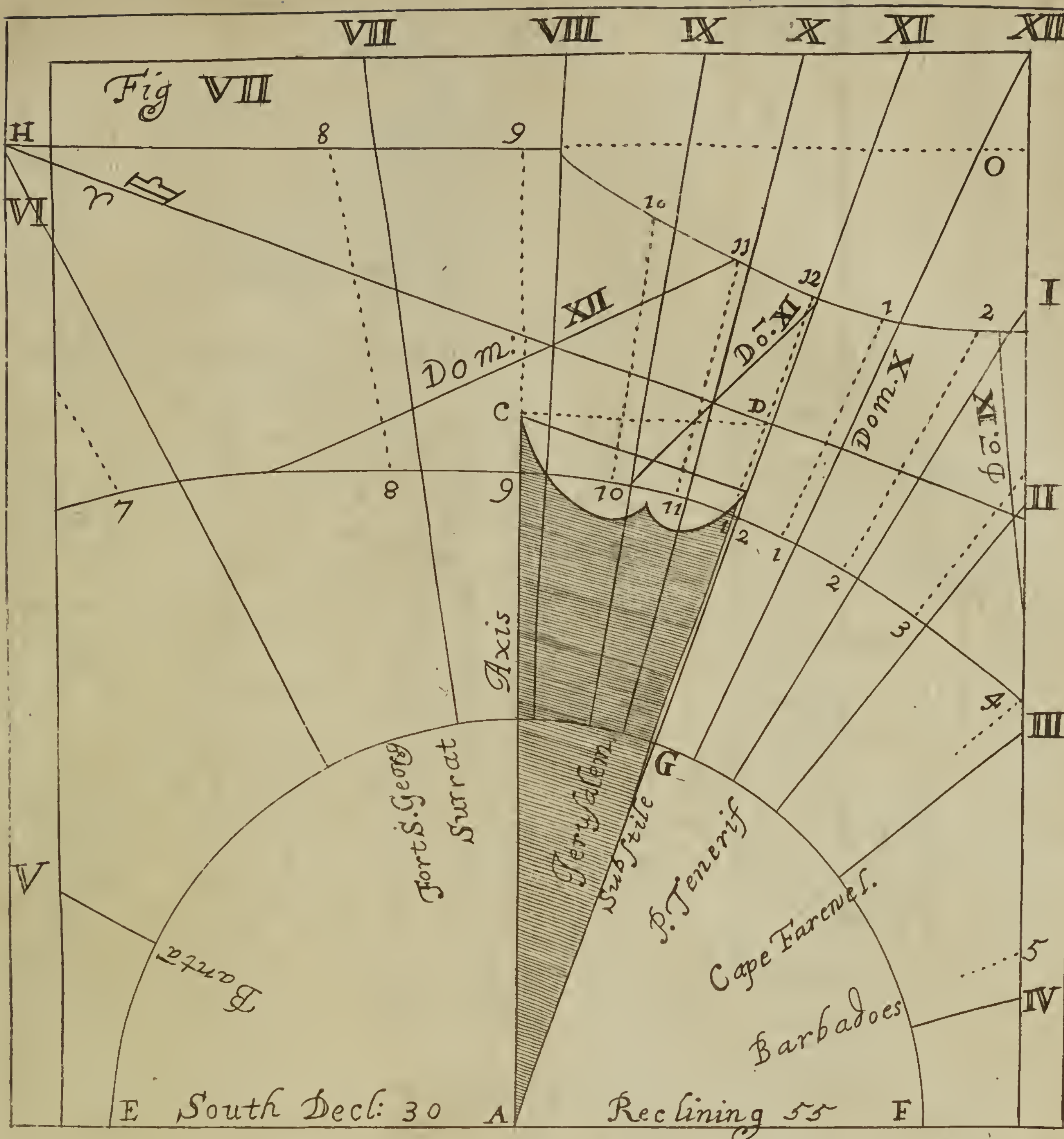
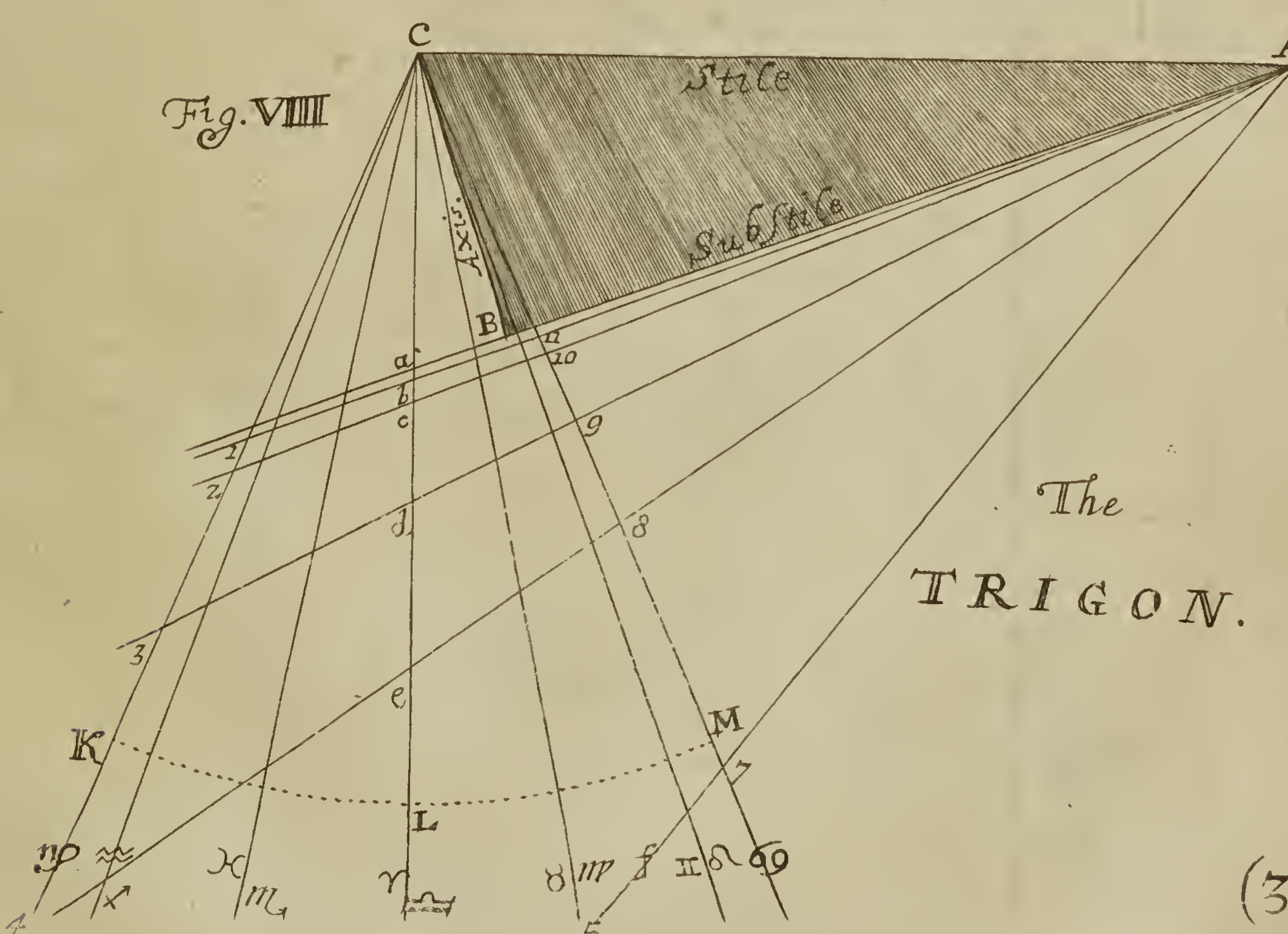


Fig. VIII



The

TRIGON.

A South Diall Declining East with its Furniture.

Figure IX.

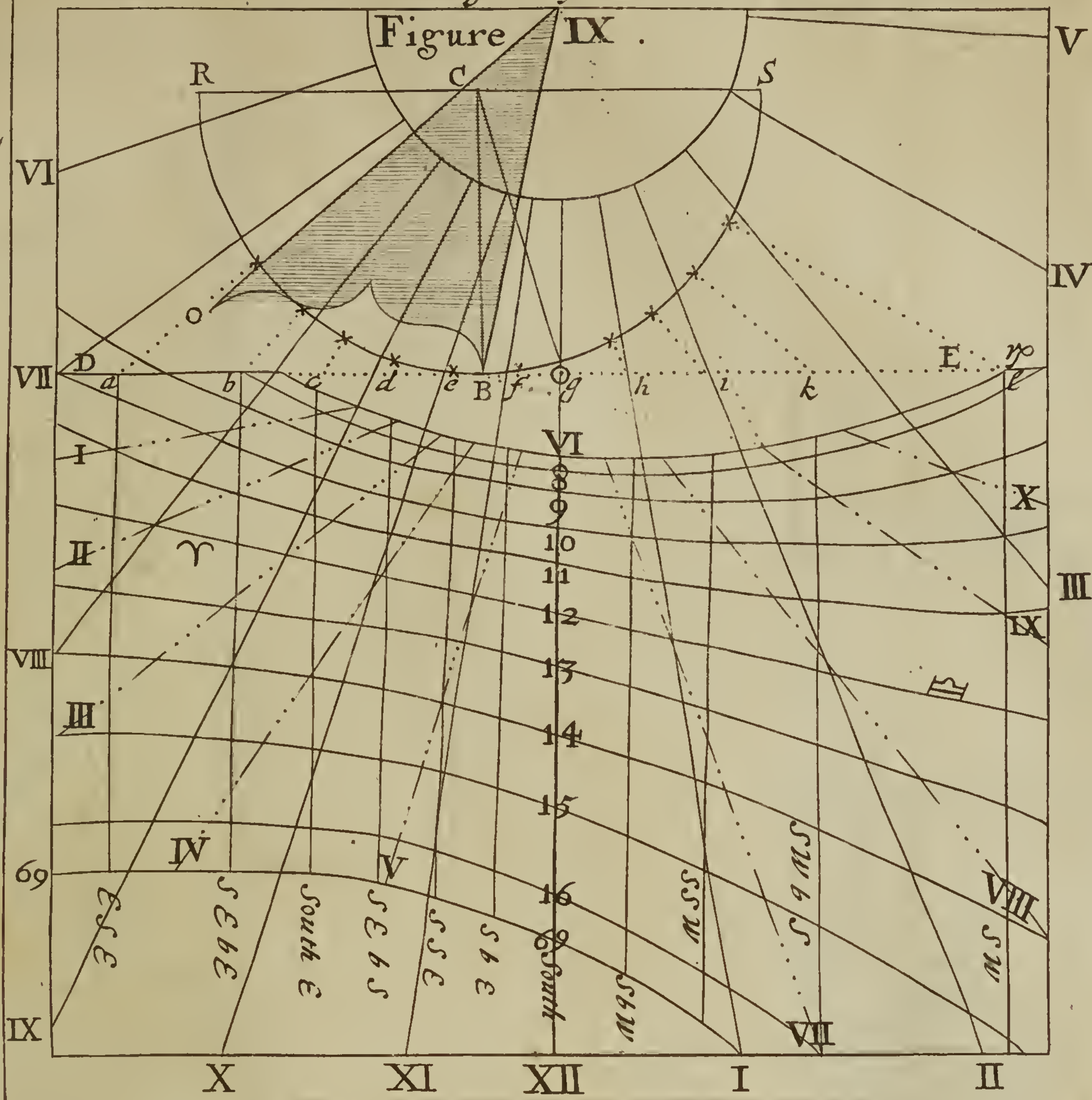
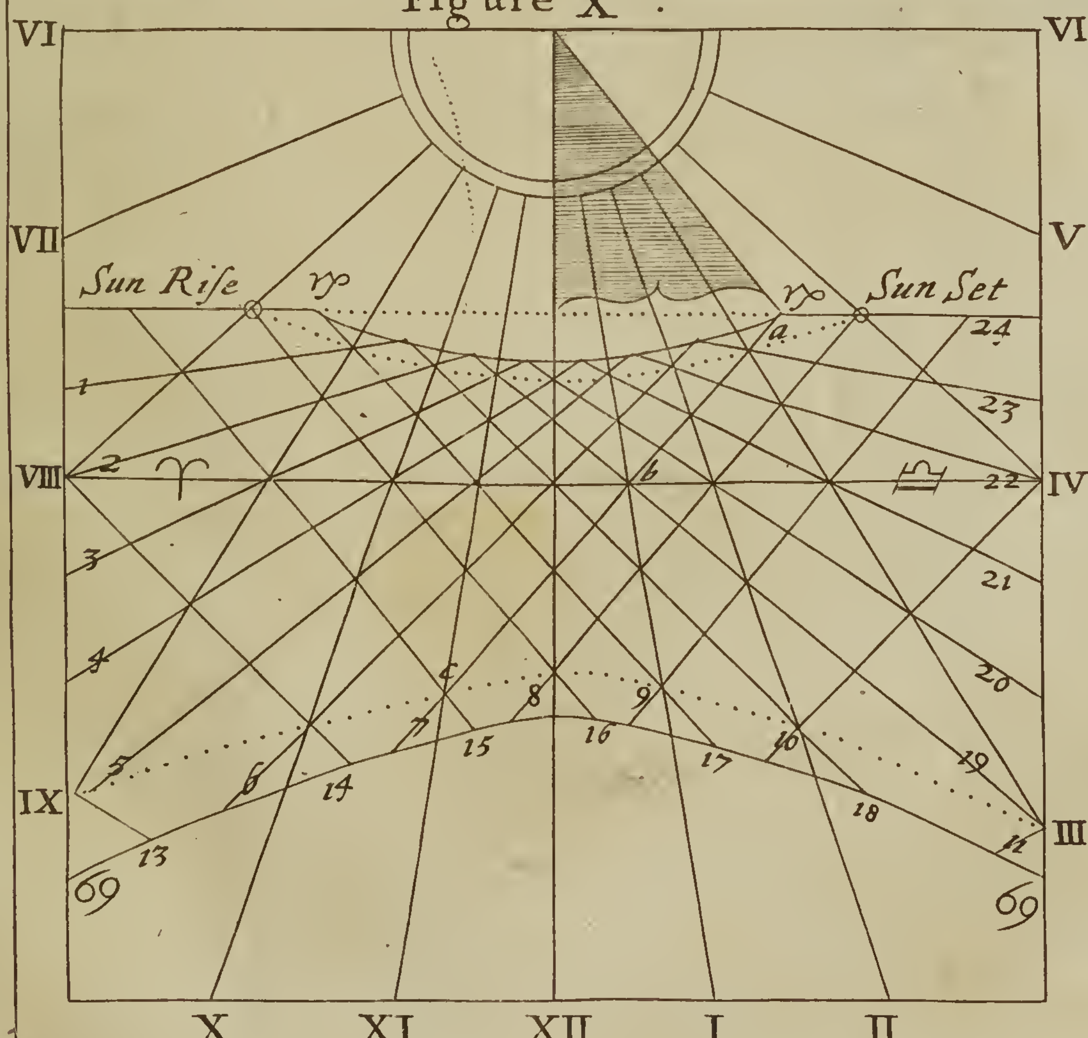


Figure X.



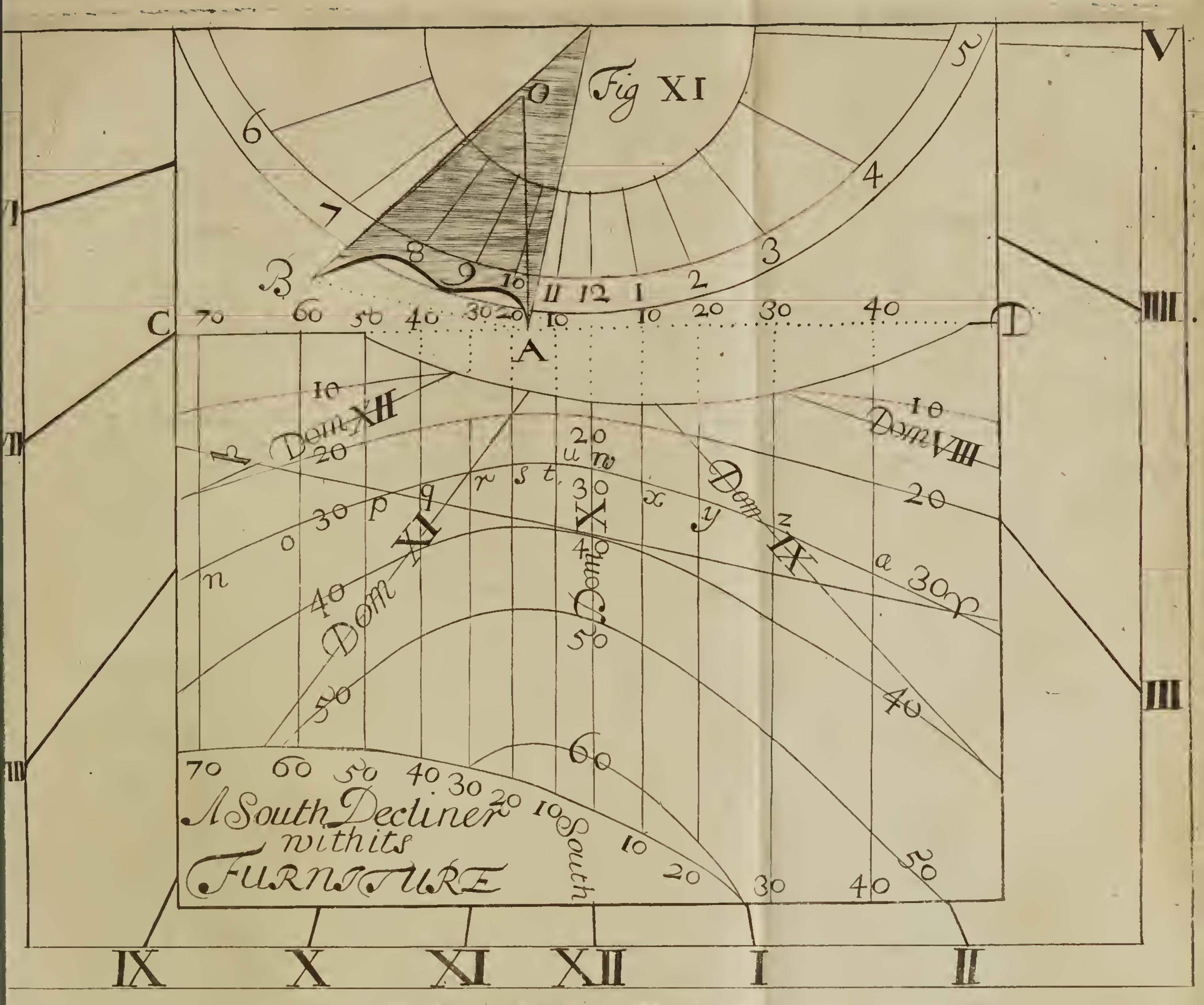


Fig XI
A South Decliner
with its
FURNITURE
South
Dom XII
Dom XI
Dom X
Dom IX
Dom VIII
IX X XI XII I II
The Trigon
West side of the
Plaine
East side of the Plaine
(5)

A West Plain Reclining with its Furniture.

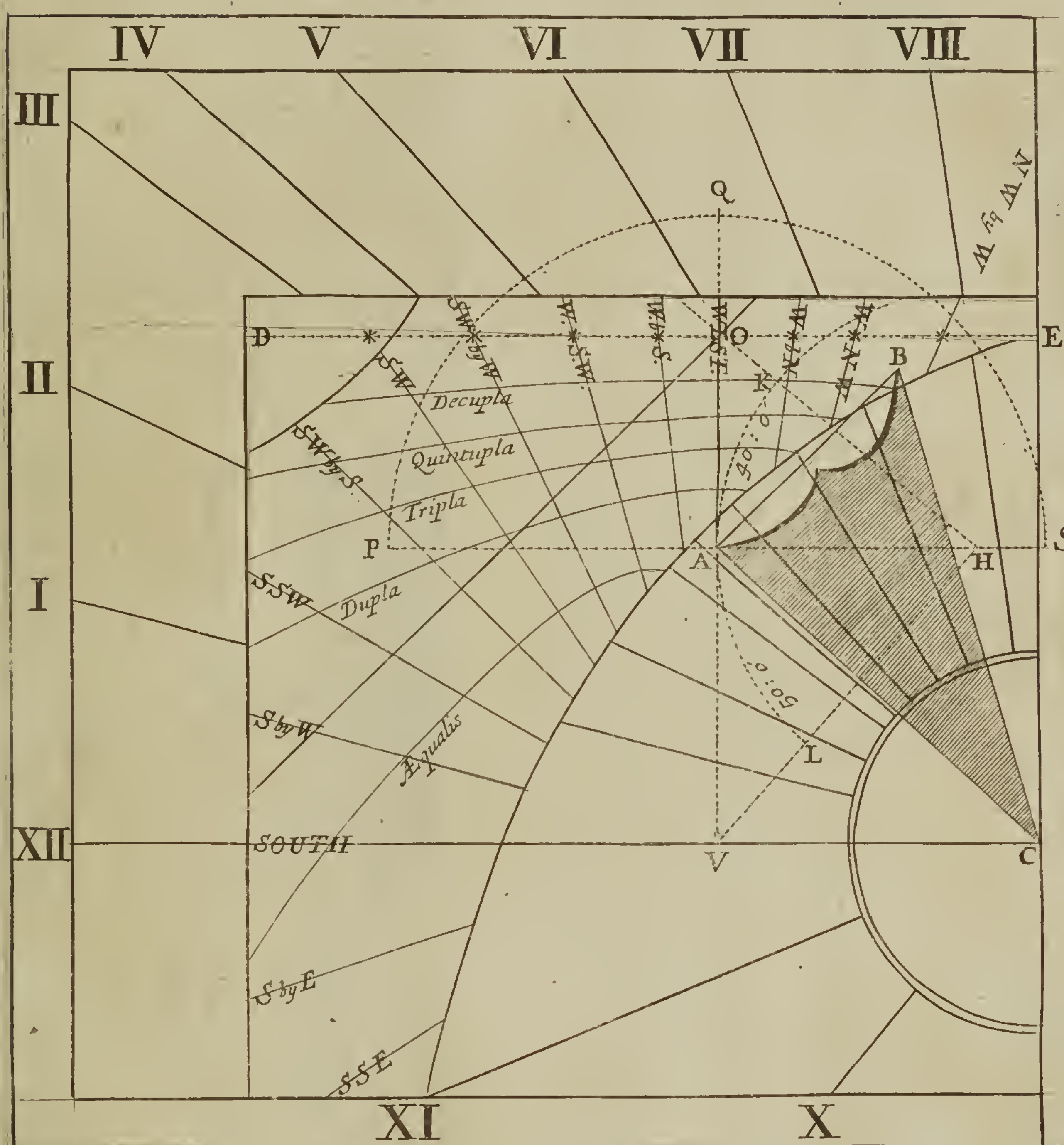


Figure XII

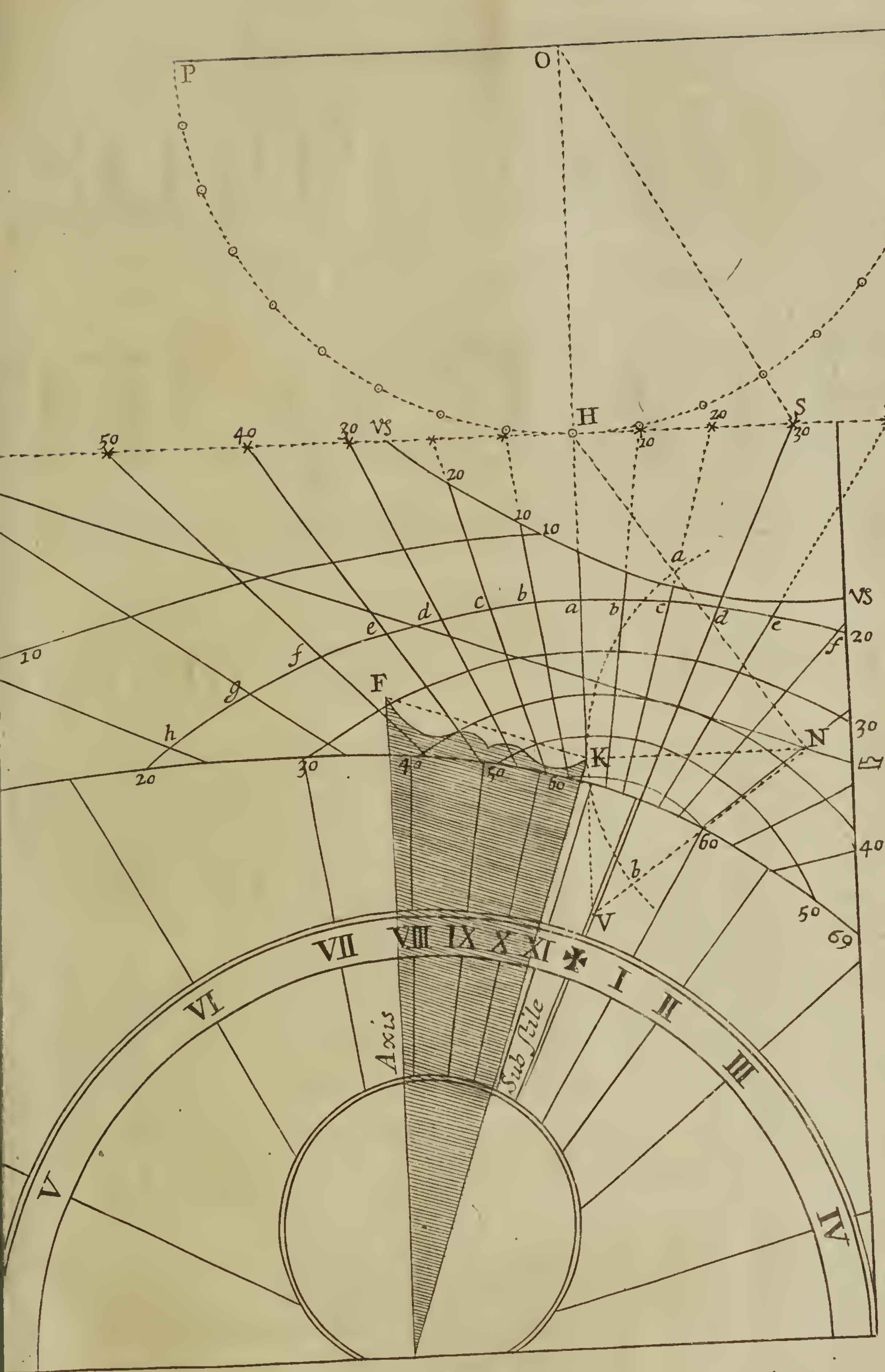
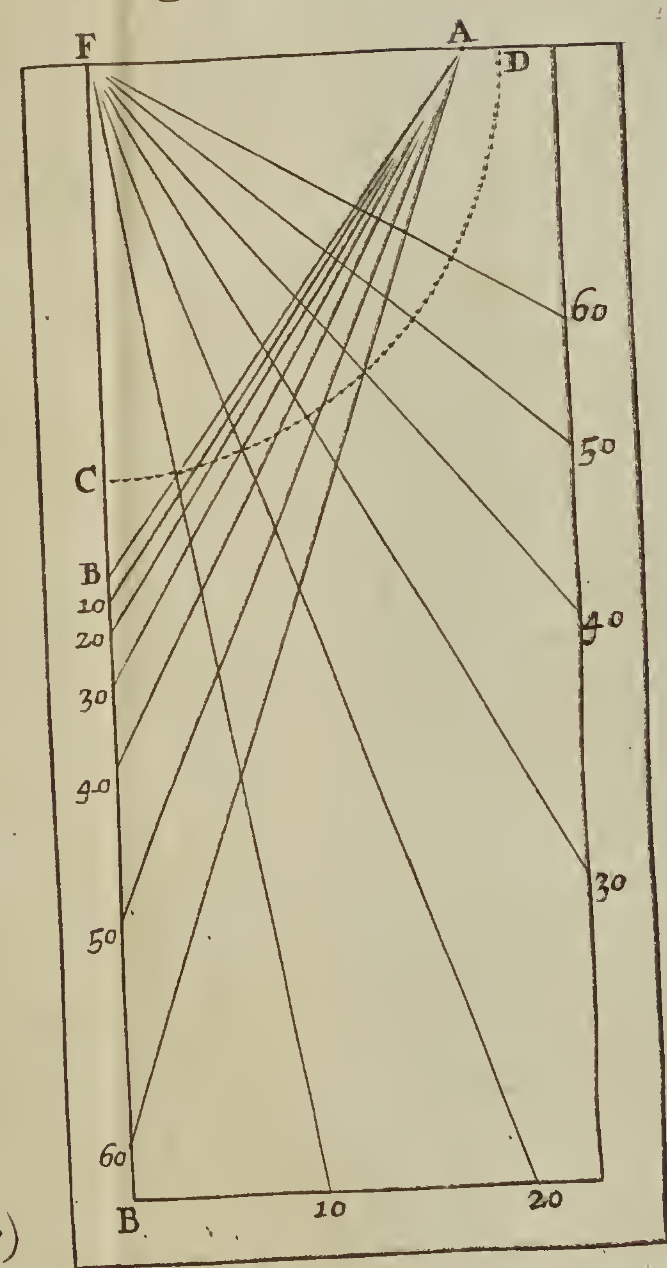


Figure XIII. South { Declining 30.^{de} / Reclining 55.^{de}

Fig: XIV.



A SUPPLEMENT
To the Two Foregoing
TRACTATES,
Concerning the *Form* of the *PARALLELS* OF *DECLINATION* and *ALTITUDE* And other *LINES* of the *FURNITURE* OF
SUN-DIALS.

Which when they are neither *Right Lines* nor *Arches* of *Circles*, but *Conick Sections*, to know at any *Time*, and upon any *Plain*, what *Section* the Shadow of the *Apex* or *Point* of the *Gnomon* traceth out upon the *Plain*, whether it be *Parabolical*, *Hyperbolical*, or *Elliptical*.

HAVING in the two foregoing Tractates taught ſeveral ways how to inſcribe the *Parallels of the Sun's Courſe*, the *Azimuths*, *Almicanthars*, *Babyloniſh*, *Italian* and *Jewiſh hours* upon all *Dial-Plains*, as being things of moſt frequent uſe, yet in the following IXth. Tractate, is ſhewed how *Dial-plains* may be furniſhed with other Varieties, as of the *Signs Aſcending*, *Deſcending*, and *Culminating*, the Horizons of other remoter Countries, and ſeveral other *Gnomonical Conclusions*.

Having, I ſay, there ſhewed the manner how to inſcribe the foremen-tioned *Spherical Lines* of the *Sun's Courſe* upon *Dial-plains* : It remains now that I ſhould ſay ſomewhat concerning the *Form* of theſe *Parallels* when they are deſcribed upon *Dial-plains*, which, when they are not *Circles*, or *Strait Lines* (as under the *Poles*) they are all, and always, *Conick Sections*, as is demonſtrated by *Mydorgius*, in the 34. *Prop.* of his *Book*. But to paſs by his *Demonſtrations* (as not at all proper for this place, this being a *Book* of *Practice* and not ſo much of *Demonſtration*) it ſhall be here ſhewed, how, at any time, or place, it may be known what *Section* the

 Shadow

Shadow of the *Apex* or top of the *Gnomon* traceth out upon any *Dial-plain*; And although this be not absolutely necessary for the *Diallist* to know, for without the knowledge hereof he may make and finish his *Dial*, as hath been already taught.

For the Illustration of the Nature of these *Parallels of Altitude*, and the *Sun's Course* upon *Dial-plains*; I shall deliver *Three* brief *Rules*, which are proved by *Aquilonius* in the 83*d Prop.* of his Sixth *Book of Opticks*, which *Rules* follow.

RULE I.

When the Sun is in any Parallel, *if the* Plain *of the* Dial *be Parallel to a* Great Circle *of the Sphere*, *which* toucheth *the* Parallel, *and the* opposite *thereunto, the Projection of the* Shadow *of the* Apex *shall be a PARABOLA.*

RULE II.

If the Dial-Plain *be* Equidistant *to a* Great Circle *which* cuts *the* Parallel, *and the* opposite *thereunto*, *the* Shadow *of the* Apex *runs in an HYPERBOLA.*

RULE III.

If the Dial-plain *be* Equidistant *to a* Great Circle; *which neither* Toucheth *nor* Cutteth *the* Parallel, *the* Shadow *of the* Apex, *or* Top *of the* Perpendicular Stile (*for so is meant all this while*) *shall trace out an ELLIPSIS.*

For Illustration of the Three *foregoing* Rules, *have recourse to the following Figure.*

But first it will be requisite to acquaint you with a *CONE*, and the several *Sections* thereof.

First then, A *CONE* (as it is defined by *Euclide* in the 18th. 19th. and 20th. *Definitions* of his *Eleventh Book)* is a *Figure* made, when one Side of a *Rectangled Triangle (viz.* one of those that contain the right Angle*)* remaining *fixed*, the *Triangle* is turned round about, till it return to the place from whence it first moved. And if the fixed right Line, be *equal* to the other, which containeth the *right Angle*, the *Cone* is *A right Angled Cone*, but if it be *less*, it is an *Obtuse Angled Cone*: if *Greater*, an *Acute Angled Cone* —— The *Axis* of a *Cone*, is that *fixed Line* about which the *Triangle* is moved —— The *Base* of a *Cone*, is the *Circle* which is described by the *right Line* moved about.

Figure I. 1. In this Figure, Let A B X C represent a *Cone*, then the *Cone* cut off by a *Line* O P *parallel* to the *Base* A B, the *Section* so cut shall be a *Circle*.

2. If the *Cone* be cut off by a *Line* K G, *parallel* to the *Axis* of the *Cone* A X, the *Section* so cut off shall be an *Hyperbola*.

3. If the *Cone* be cut by a *Line* F D, parallel to any of the Sides of the *Cone*, (as F D parallel to A B*)* the *Section* so cut off shall be a *Parabola*.

4. If the *Cone* be cut obliquely through the *Axis* and Sides, as by the *Line* N H, the *Section* so cut off shall be an *Ellipsis*.

Wherein

Fig. I.

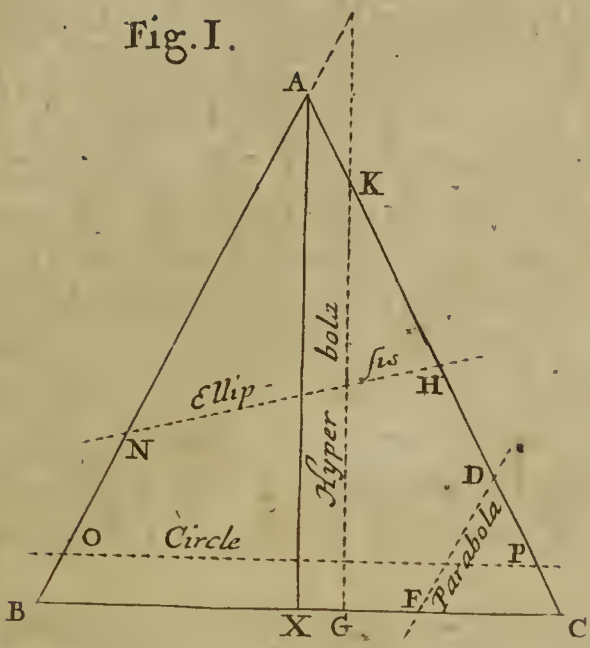
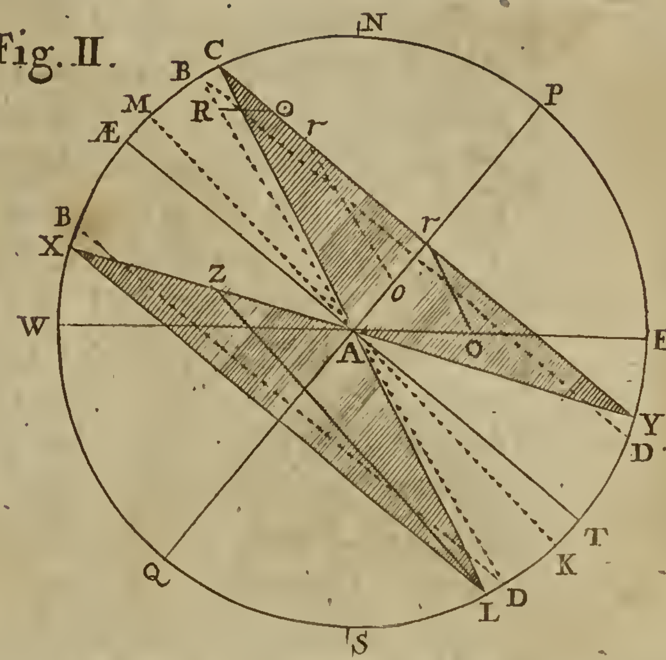


Fig. II.



Wherein the outward or primitive *Circle* W N E S, represents the *Meridian* of the *Globe*. *General Figure* II.

N and S, the Point of *Zenith* and *Nadir*.

W E, The *Horizon*.

E P, 51 deg. 32 min. the heighth of the *North Pole*, or the *Latitude* of *London*.

P Q, The *Prime Vertical Circle*, and *Axis* of the *World*.

P, The *North*, and Q, the *South Poles*.

Æ T, The *Equinoctial* or *Equator*.

C L, The *Ecliptick*.

C Y, and X L, The two *Tropicks*.

B D, An intermediate *North Parallel* of the *Sun's Course* or *Declination*.

I. Now from the *Scheme* it is evident, that the *Horizontal Dial* for the Latitude of *London* 51 deg. 32 min. being *equidistant* to the *Great Circle*, or *Horizon* W E, which cuts the *Tropicks*, and all the *Parallels* between them, as that of B D, or any other, is (according to the First *Rule)* such, that the *Shadow* of the *Apex* of the *Stile* shall thereupon, all the year long, trace out *Hyperbolas*; but of different kinds, as the *Plain* shall *cut* several *Parallels*, more or less unequally.

II. But if a *Dial* were made *parallel* to the *Ecliptick* C L, which only *toucheth* the *Tropicks* (and doth not *intersect* or *cut* them) the *Shadow* of the *Apex* thereupon, when the Sun is in the *Tropicks*, shall trace out *Parabolas*.

III. If a Plain were *equidistant*, not to the *Equator* Æ T, but to some other *Plain* as M K, whose *Great Circle* neither *Touches* any of the *Parallels*, nor *Cuts* them, the *Shadow* of the *Apex* of the *Stile* there, shall always trace out some *Ellipsis*, but not always the same; but *lesser* as the *Sun* or his *Parallel* approacheth nearer the *Equator*, and *greater* in those *Horizons* which make more acute Angles with the *Equator*; until (at last) the *Horizon* W E, and the *Equator* Æ T, become co-incident; And then the *Projection* of the *Shadow* made by the *Apex* of the *Stile* shall trace out a perfect *Circle*.—— Likewise let the *Horizon* be howsoever situate, if the *Sun* be in no *Parallel*, but in the *Equator* it self, the *Projection* of the *Shadow* made by the *Apex* of the *Stile*, shall be a *right* or *strait Line*.

I shall not here insert the *Demonstration* which *Aquilonius* useth to prove these three *Rules*, but endeavour to make it plain enough otherwise.

I. The

I. The Sun being in the *Southern Signs*, suppose the *dark Cone* C A Y in *North Latitude*, to be cut by a *Plain* C A Y, through the *Vertex* at A, *perpendicular* to the *Center* of the *Base* of the *Cone*, it gives the Triangle C A Y for the flat, and under *Superficies* of the *Semi-Cone* C A Y —— Now let *r o* (which is drawn with a *full Line*) be the *Horizon*, or *Dial-Plain*, (for every *Dial-Plain* is *parallel* to some *Horizon* or other, as is before intimated) and let it be *equidistant* to C A, then the *Common Section r o* (which while the *Sun* is in the *Tropick* X) distinguisheth (or rather) separateth, the *Light* from the *Darkness*; *As by the general Definition of a Cone.* —— *A Semi-Parabola* in like sort might be proved, if the Sun were in any other *Parallel*, as suppose in the *Parallel* B D, for supposing the *pricked Line r o*, to represent the *Dial-Plain*, *parallel* to B A, the same Conclusion follows, from the said *general Definition of a Cone.*

II. Let the *Dial-Plain* be R ⊙, *parallel* to the *great Circle* or *Horizon* W E, which cuts the *Parallel* C Y in ⊙, then (by the said *Definition General*) the *Common Section* R ⊙, which that day separates the *Light* and *Darkness* upon the *Plain*, is a *Semi-Hyperbola.* —— Or, if instead of the *Semi-Cone*, one conceive the *Section* of the *Cone*, through the *Vertex* and *Axis* to be the *plain Triangle*, C A Y, and R ⊙ a *right Line*, to be only the *Diameter* of the *Section*, the thing is the same, and the *Section*, (by the 2. *Definit.* of the Third of *Mydorgius*) is an *Hyperbola.*

III. Lastly, (to avoid confusion of *Lines*, and multiplicity of *Schemes*) Let the *Sun* be in the *Northern Signs*, and X A L the *dark Cone*, and Z L the *Dial-Plain*, in South Latitude; *equidistant* to the *great Circle* M K, which neither *cutteth* nor *toucheth* the *Parallels*; it is evident, that Z L, or any Line *equidistant* to M K, shall cut the *Triangle* X A L, made from a *Section* from the *Vertex* as before, in both the Sides X A, and L A, and is therefore (by the 3*d.* of the 3*d. Definition* of *Mydorgius*) the *Diameter* of an *Ellipsis*, or (by the *general Definition* of a *Cone*) it is half an *Ellipsis* —— And so, any other *Line parallel* to Z L, and *greater* than X L, is the *Diameter* of a greater *Ellipsis*, or rather, an *Ellipsis* of a *greater Cone*, which might be made, by producing the Lines A X and A L at pleasure.

This that hath been here delivered is (I hope) proof sufficient, for what hath been said of this matter, and I hope enough to make it intelligible.

The End of the SUPPLEMENT.

A CONNEXION OF TABLES

Of divers Kinds,

Calculated for ſeveral *Elevations* of the *Pole* (or *Latitudes*) very uſeful, and really ſubſervient to the ART

OF DIALLING:

THE WHICH

With the *TABLE* of Natural *SINES*, *TANGENTS*, and *SECANTS*, (hereunto annexed) and a *SCALE* (or *Sector* rather) having *Equal Parts* upon it; The *Parallels* of the *Signs* and *Diurnal Arches*, the *Azimuths*, *Almicánters*, the *Jewiſh*, *Italian* and *Babyloniſh Hours*, and other *FURNITURE*, may eaſily (and more exactly than by any other Means) be inſcribed upon all *Dial-Plains* whatſoever.

The SIXTH TRACTATE.

A TABLE, ſhewing what *Declination* the Sun ſhall have, he being in any Degree of the *Ecliptick.*

Degrees of the Ecliptick for *Northern* Signs.	Northern Signs.																		Degrees of the Ecliptick for *Southern* Signs.
	Aries ♈			*Taurus* ♉			*Gemini* ♊			*Cancer* ♋			*Leo* ♌			*Virgo* ♍			
	D.	M.	S.	D.	M.	S.	D.	M.	S.	D.	M.	S.	D.	M.	S.	D.	M.	S.	
0	0	0	0	11	30	44	20	13	21	23	31	30	20	13	41	11	30	44	30
1	0	23	57	11	51	48	20	25	57	23	31	10	19	59	59	11	9	28	29
2	0	47	53	12	12	41	20	38	59	23	30	35	19	47	7	10	48	2	28
3	1	11	49	12	33	21	20	49	9	23	29	17	19	33	27	10	26	25	27
4	1	35	44	12	53	50	21	1	15	23	27	51	19	19	26	10	4	38	26
5	1	59	37	13	13	5	21	12	28	23	25	48	19	5	5	9	42	42	25
6	2	23	28	13	34	8	21	23	8	23	23	18	18	50	22	9	20	36	24
7	2	47	18	13	53	57	21	33	23	23	20	21	18	35	20	8	58	21	23
8	3	11	4	14	13	32	21	43	15	23	16	57	18	19	48	8	35	38	22
9	3	34	48	14	32	52	21	52	43	23	13	6	18	4	16	8	13	13	21
10	3	58	28	14	51	59	22	1	45	23	8	48	17	48	15	7	58	27	20
11	4	22	55	15	10	51	22	10	22	23	4	3	17	31	56	7	28	0	19
12	4	45	37	15	29	27	22	18	35	22	58	52	17	15	18	7	5	6	18
13	5	9	5	15	47	47	22	26	22	22	53	14	16	58	22	6	42	6	17
14	5	32	29	16	5	52	22	33	44	22	47	1	16	41	9	6	18	59	16
15	5	55	47	16	23	38	22	40	40	22	40	40	16	23	38	5	55	47	15
16	6	18	59	16	41	9	22	47	1	22	33	44	16	5	52	5	32	29	14
17	6	42	6	16	58	29	22	53	14	22	26	22	15	47	47	5	9	5	13
18	7	5	0	17	15	18	22	58	52	22	10	35	15	29	27	4	45	37	12
19	7	28	0	17	31	56	23	4	3	22	10	22	15	10	51	4	22	55	11
20	7	50	7	17	48	15	23	8	48	21	1	45	14	51	59	3	58	27	10
21	8	13	13	18	4	16	23	13	6	21	52	43	14	32	52	3	34	48	9
22	8	35	38	18	19	48	23	16	57	21	43	15	14	15	32	3	11	4	8
23	8	58	21	18	35	20	23	20	21	21	33	23	13	53	57	2	47	18	7
24	9	20	36	18	50	22	23	23	18	21	23	8	13	34	8	2	23	28	6
25	9	42	42	19	5	5	23	25	48	21	11	28	13	13	5	1	59	37	5
26	10	4	38	19	19	26	23	27	51	21	1	15	12	53	50	1	35	44	4
27	10	26	25	19	33	27	23	29	17	20	49	9	12	33	21	1	11	49	3
28	10	48	2	19	47	7	23	30	35	20	38	59	12	12	41	0	47	53	2
29	11	9	28	19	59	59	23	31	16	20	25	57	11	51	48	0	23	57	1
30	11	30	44	20	13	21	23	31	30	20	13	21	11	30	44	0	0	0	0
	Piſces ♓			*Aquarius* ♒			*Capricorn* ♑			*Sagitary* ♐			*Scorpio* ♏			*Libra* ♎			
	Southern Signs.																		

The

The *Description*, *Construction*, and *Use* of this *Table*.

I. *Its Description*.

THe Table consisteth of Eight Columns; The first of which towards the right hand contains the Degrees that the Sun is in, being in any of the Six Northern Signs, (*viz. Aries* ♈, *Taurus* ♉, *Gemini* ♊, *Cancer* ♋, *Leo* ♌ or *Virgo* ♍) placed at the head of the Table. —— And the last Column towards the right hand, contains the Degrees that the Sun is in, in any of the Six Southern Signs (*viz. Libra* ♎, *Scorpio* ♏, *Sagittarius* ♐, *Capricorn* ♑, *Aquarius* ♒ and *Pisces* ♓) which are placed at the foot of the Table: —— And in the other Six Columns you have the Declination that the Sun hath, he being in any Degree of any Sign of the Zodiack.

II. *Its Construction*.

The Place of the Sun in the Ecliptick being known, the Declination of the Sun from thence may be easily deduced, by this following Analogy or Proportion.

As the Sine of 90 Degrees	10.0000000
Is to the Sine of the Sun's greatest Declination 23 deg. 31 min.	9.6006997
So is the Sine of the Sun's distance from *Aries* or *Libra*, (suppose 19 deg.)	9.5126419
To the Sine of 7 deg. 28 min. the Sun's Declination, when he is in 19 deg. of *Aries* or *Libra*.	19.1133416

And in the same manner may you find that when the Sun is in 13 deg. of *Taurus* or *Scorpio*, the Sun's Declination will be 15 deg. 48 min. *ferè*, *viz.* 15 deg. 47 min. 47 Seconds, *&c.*

In what Sign and Degree of the Ecliptick the Sun will be any day of the Year may be found (exact enough for Instrumental Performances) by memory, if it be remembred that upon the first day of

January,	*February*,	*March*,	*April*,	*May*,	*June*,
the Sun is in					
21 ♑,	22 ♒,	20 ♓,	21 ♈,	20 ♉,	19 ♊,
July,	*August*,	*September*,	*October*,	*November*,	*December*,
the Sun is in					
18 ♋,	18 ♌,	18 ♍,	17 ♎,	18 ♏,	19 ♐.

For if you add the Days of the Month to the Degrees of the Sign that the Sun is in on the first day of the Month, the Sum is the degrees of that Sign the Sun is in; if the Sum exceed 30 it is in the following Sign; So

in

in the Seventh of *May* the Sun will be in 27 degrees of *Taurus*; And on the Eighteenth of *October* the Sun will be in 5 degrees of *Scorpio*, *&c.*

III. *Its Uſe.*

Seek the Sign that the Sun is in, if it be a *Northern* *Southern* Sign in the *Head* *Foot* of the Table, and the degree of that Sign in the *First* *Last* Column of the Table and in the Common Section or Angle of meeting of thoſe two you have the Declination: So the Sun being in 25 deg. of *Leo*, ſeek *Leo* (it being a Northern Sign) in the Head of the Table, and 25 deg. in the firſt Column, and under *Leo*, and againſt 25 deg. you ſhall find 13 13 5. which ſhews that when the Sun is in 25 deg. of *Leo*, he hath 13 deg. 13 min. and 5 Seconds of Declination: —— Alſo the Sun being in 17 deg. of *Capricorn*, ſeek *Capricorn* (it being a Southern) at the Foot, or bottom of the Table, and the 17 deg. in the laſt Column, and over *Capricorn*, and againſt 17 deg. you ſhall find 22 26 22 ſhewing that the Sun being in 17 deg. of *Capricorn*; his Declination will be 22 deg. 26 min. 22 Seconds: And ſo of the Reſt. And

Note, If the Sun be in a *Northern* *Southern* Sign, the Sun hath *North* *South* Declination.

A

A TABLE ſhewing the length of the Artificial Day or Night, the Sun being in any Degree of the Ecliptick for 12 ſeveral Degrees of Latitude, *viz.* from 44 to 57 Degrees.

Degrees of Latitude; Or, Elevation of the Pole.

	45		46		47		48		49		50		51		52		53		54		55		56		
	h.	m.	h.	m.	h.	m.	h.	m.	h.	m.	h.	m.	h.	m.	h.	m.	h.	m.	h.	m.	h.	m.	h.	m.	
♈ ○ ♎	6	0	6	0	6	0	6	0	6	0	6	0	6	0	6	0	6	0	5	0	5	0	6	0	♎ ○ ♈
1		1		1		1		1		1		1		1		1		1		1		2		2	29
2		3		3		3		3		3		3		3		3		3		3		4		5	28
3	6	5	6	5	6	5	6	6	6	6	6	6	6	6	6	6	6	6	5	7	6	7	6	7	27
4		7		7		7		8		8		8		8		8		9		9		10		10	26
5		8		8		8		10		10		10		10		11		11		11		12		12	25
6	6	10	6	10	6	10	5	11	6	11	6	11	6	12	6	12	6	13	5	13	6	14	6	14	24
7		12		12		12		13		13		13		14		14		15		15		16		16	23
8		13		13		13		15		15		15		16		16		17		17		18		19	22
9	6	14	6	15	6	15	5	16	6	16	6	17	6	18	6	18	6	19	5	20	6	20	6	21	21
10		16		16		17		18		18		19		20		20		21		22		22		23	20
11		17		18		19		20		20		21		22		22		23		24		25		25	19
12	6	19	6	20	6	20	6	21	6	22	6	23	6	24	5	24	6	25	5	26	5	27	6	28	18
13		21		22		22		22		23		25		26		26		27		28		29		30	17
14		23		23		24		24		25		27		27		28		29		30		31		32	16
15	6	24		25	6	26	6	26	6	27	6	28	6	29	5	31	6	32	5	33	6	34	5	35	15
16		25		27		28		28		29		30		31		33		34		35		37		37	14
17		27		29		30		30		31		32		33		35		36		37		39		39	13
18	6	29	6	30	6	31	6	32	6	33	6	34	6	35	5	37	6	38	5	39	5	41	6	42	12
19		30		31		32		34		35		36		37		39		40		42		44		45	11
20		32		33		35		36		37		38		39		41		42		44		46		47	10
21	6	33	6	34	6	36	6	37	6	38	6	40	6	4[illegible]	5	43	6	44	6	46	5	48	6	49	9
22		35		36		38		38		40		41		4[illegible]		45		46		48		50		51	8
23		37		38		40		40		42		43		45		47		48		50		52		54	7
24	6	38	6	39	6	41	6	42	6	44	6	45	6	47	5	49	6	50	6	52	6	54	6	56	6
25		40		41		43		43		46		47		49		51		53		54		56		59	5
26		41		43		45		45		48		49		51		53		55		57		58	7	1	4
27	6	43	6	44	6	46	6	47	6	49	6	51	6	53	6	55	6	57	6	59	7	1	7	3	3
28		44		45		47		49		51		53		55		57		59	7	2		3		5	2
29	6	46		47		48		50		53		54		56		59	7	1	7	3		5		7	1
♉ ○ ♏	6	47	6	49	6	50	6	52	6	54	6	56	6	58	7	0	7	3	7	5	7	8	7	10	♍ ○ ♓
1		49		51		52		54		56		58	7	0		2		5		7		10		14	29
2		50		52		53		56		57	7	0		2		4		7		9		12		10	28
3	6	51	6	53	6	55	6	57	6	59	7	1	7	4	7	6	7	9	7	11	7	14	7	17	27
4		52		54		57		59	7	1		3		6		8		11		13		16		19	26
5		54		56		59	7	0		3		5		7		10		13		15		19		21	25
6	6	56	6	57	7	0	7	2	7	4	7	7	7	9	7	12	7	15	7	17	7	21	7	24	24
7	6	57		58	7	2		4		6		9		11		14		17		19		23		2[illegible]	23
8	6	58	7	0		3		6		8		10		13		16		19		21		25		28	22
9	6	0	7	2	7	5	7	7	7	9	7	12	7	15	7	17	7	20	7	24	7	27	7	30	21
10		1	7	4		6		9		11		13		17		19		22		27		29		32	20

Degrees of Latitude; Or, Elevation of the Pole.

	45	46	47	48	49	50	51	52	53	54	55	56	
	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	
♉ ○ ♏	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	6 0	♍ ○ ♓
11	7 3	6	8	11	13	15	19	21	24	29	31	35	19
12	7 4	7 7	7 9	7 12	7 15	7 17	7 20	7 23	7 26	7 30	7 33	7 37	18
13	5	9	11	13	16	19	21	25	28	32	35	39	17
14	7	10	12	15	18	21	23	27	30	33	37	41	16
15	7 9	7 11	7 13	7 17	7 19	7 22	7 25	7 28	7 32	7 35	7 39	7 43	15
16	10	12	15	18	21	23	27	30	34	37	41	45	14
17	11	13	17	19	23	25	29	32	36	39	43	47	13
18	7 12	7 15	7 18	7 21	7 24	7 26	7 30	7 34	7 37	7 41	7 45	7 49	12
19	13	16	20	22	25	28	31	36	39	43	47	52	11
20	14	13	21	23	26	29	33	38	40	45	49	54	10
21	7 16	7 19	7 22	7 25	7 28	7 31	7 35	7 39	7 42	7 47	7 51	7 56	9
22	17	20	23	26	30	32	36	41	44	49	53	58	8
23	19	21	25	28	31	34	37	42	46	50	55	55	7
24	7 20	7 23	26	7 29	7 32	7 36	7 39	7 43	7 48	7 52	7 56	8 1	6
25	21	24	7 27	30	34	37	41	45	50	54	88	3	5
26	22	25	28	31	35	39	42	46	51	56	8 0	5	4
27	7 23	7 26	7 29	7 33	7 36	7 40	7 44	7 48	7 52	7 57	8 2	8 7	3
28	24	27	30	33	37	41	45	50	53	59	4	9	2
29	25	28	32	35	38	42	46	51	55	8 0	6	11	1
♊ ○ ♐	7 26	7 30	7 33	7 36	7 40	7 44	7 48	7 52	7 57	8 2	8 7	8 12	♌ ○ ♒
1	27	31	34	37	41	45	50	53	59	3	9	13	29
2	28	32	35	39	43	47	51	55	59	5	10	15	28
3	7 29	7 33	7 36	7 40	7 44	7 48	7 52	7 56	8 1	8 6	8 12	8 17	27
4	30	34	37	41	45	49	53	58	2	7	13	19	26
5	31	35	38	42	46	50	54	59	3	9	14	21	25
6	7 32	7 36	7 39	7 43	7 47	7 51	7 56	8 0	8 5	8 10	8 16	8 22	24
7	33	36	40	44	48	52	57	1	6	11	17	23	23
8	34	37	41	45	49	53	58	2	7	13	18	25	22
9	7 35	7 38	7 42	7 46	7 50	7 54	7 59	8 4	8 9	8 14	8 20	8 26	21
10	36	39	42	45	51	55	3 0	5	9	15	21	28	20
11	37	39	43	47	52	56	3 1	6	11	16	22	29	19
12	7 37	7 40	7 44	7 48	7 53	7 57	3 2	8 7	8 12	8 17	8 23	8 30	18
13	38	40	45	49	53	57	2	8	13	18	24	31	17
14	39	41	46	49	54	58	3	8	14	19	25	32	16
15	7 39	7 42	7 46	7 50	7 55	7 59	8 4	8 9	3 15	8 20	8 26	33	15
16	39	43	47	50	55	59	5	9	15	21	27	34	14
17	40	43	47	51	56	8 0	6	10	16	22	28	35	13
18	7 40	7 44	7 48	7 52	7 57	8 1	8 7	8 11	8 17	8 23	8 29	8 36	12
19	40	44	48	53	57	1	7	11	18	23	29	37	11
20	41	44	48	53	58	2	8	12	18	24	30	37	10
21	7 41	7 45	7 49	7 54	7 58	8 3	8 8	8 13	8 19	8 25	8 31	8 38	9
22	41	45	49	54	58	3	8	13	19	25	31	38	8
23	42	46	49	55	59	4	9	14	20	26	32	38	7
24	7 42	7 46	7 50	7 55	7 59	8 4	8 9	8 14	8 20	8 26	8 33	8 39	6
25	42	46	50	55	59	4	9	14	20	27	33	39	5
26	43	47	50	56	8 0	4	10	15	21	27	33	39	4
27	7 43	7 47	7 51	7 56	3 0	8 4	8 10	8 15	8 21	8 27	8 33	8 40	3
28	43	47	51	56	0	4	10	15	21	27	33	40	2
29	43	47	51	56	0	4	10	15	2.	27	33	40	1
♋ ○ ♑	7 43	7 47	7 51	7 56	8 0	8 5	o 10	3 15	8 22	8 27	8 34	8 41	♋ ○ ♑

The

The Deſcription, Conſtruction *and* Uſe *of this* Table.

I. *Its Deſcription.*

The Table conſiſteth of 14 *Columns:* in the firſt towards the Left hand, and in the laſt towards the Right hand, you have the *Sign* and *Degree* that the Sun is in; and in the other 12 intermediate *Columns* you have the *Semi-diurnal* and *Semi-nocturnal* Arks, or half length of the *Artificial Day* or *Night.*

Now, the *Artificial Day* is an Arch of the *Natural Day*, and contains that ſpace of time which is numbered from the *Riſing* of the *Sun* unto the going down of the ſame; and this Arch is either *Equal* or *Unequal.* The mean or *Equal Artificial Day* contains always 12 hours, which evermore happens when the Sun is in the *Equinoctial*, but when the Sun is out of the ſame Line, it is unequal, and is then either *longer* or *ſhorter* than 12 hours, according as the Sun's Arch or *Parallel* cauſed by the greater or leſſer Elevation of the *Pole* above the *Horizon.*

II. *Its Conſtruction.*

The *Canon*, *Analogy* or *Proportion*, by which this Table is made, is this; The *Latitude* of the Place and the *Declination* of the *Sun* being known:— Let the *Latitude* be 47 deg. and let the *Sun* be in 19 deg. of *Aries*; at which time (by the former Table) the *Sun* hath 7 deg. 28. min. of *Declination*, Then the *Proportion* is.

As the Co-tangent of the *Latitude* 43 degrees	9.9696559
To the Tangent of the *Declination* 7 deg. 28 min.	9.1174724
So is the *Radius* 90 deg.	10.0000000
	19.1174724
To the *Sine* of 8 deg. 4 min.	9.1478165

This 8 deg. 4 min. converted into time is 32 min. and is the *Aſcenſional Difference* (or the diſtance in time that the Sun riſes before or after Six:) which added to Six hours (becauſe the Sun is in a Northern Sign) makes 6 hours 32 min. for the *Semidiurnal Ark*, or half length of the Day.

Note, The *Semidiurnal Ark doubled* is the length of the Day, and that doubled ſubſtracted from 24 is the *length of the Night*, and the *Aſcenſional Difference* ſubſtracted from Six hours, gives the time of the *Sun*'s *Riſing*, and added to Six hours, gives the time of the *Sun's Setting.*

III. *Its Uſe.*

Seek the Sign and Degree in which the Sun is in the firſt or laſt Column, and right againſt it (under the Latitude found at the head of the *Table*) you

ſhall

ſhall have the *Semidiurnal Ark* if the Sign in which the Sun is be a *Northern Sign*, or the *Seminocturnal Arch*, if the Sun be in a *Southern Sign*.

Example 1. *The Sun being in a Northern Sign.*

Let theSun be in the 12*th* deg.of *Gemini*,and let it be required to know the length of the day in the Latitude of 46 deg. Look for 12 deg. of *Gemini* in the First Column of the *Table*, and right againſt it (under the *Latitude* 46 deg. found in the head of the *Table*) you ſhall have 7 hours 40 min. for the *Semidiurnal Arch*, and time of the *Sun's Setting*, which doubled is 15 hours 20 min. for the *Length of the day* ——So likewiſe when the Sun is in 23 deg. of *Leo*, in the Latitude of 55 deg. the *Semidiurnal Arch* will be found to be 7 hours 23 min. which doubled makes 14 hours 46 min. for the *Length of the Day*. But,

Example 2. *The Sun being in a Southern Sign.*

Let the Sun be in 19 deg. of *Aquarius*, and let it be required to find the Length of the Day and Night, and alſo at what time the *Sun Riſes* and *Sets* in the Latitude of 48 degrees, Look for 19 deg. of *Aquarius* (which you ſhall find in the laſt Column of the *Table* towards the right hand) and right againſt it, under 48 deg of *Latitude*, you ſhall find 7 hours 11 min. which is the *Seminocturnal Arch*, and the time of the *Sun's Riſing* (becauſe the Sun is in a *Southern Sign*)——This *Arch* doubled gives 14 hours 22 min. for the *Length of the Night*. And taken out of 24 hours, leaves 9 hours 38 min. for the *Length of the day*:——The half whereof, 4 hours 49 min. is the time of the *Sun's Setting*.

Here followeth

A TABLE, *ſhewing what* Amplitude, *the* Sun *ſhall have, at his* Riſing *or* Setting, *from the true* Eaſt *or* Weſt *Points of the* Horizon; *towards either the* North *or* South: *At every whole (or equal) degree of his* Declination, Northward *or* Southward.

And for all Latitudes (*or Elevations of the Poles*) *from the* Equinoctial *to* 60 *degrees.*

Degrees

Degrees of Latitude.

Degrees of the Sun's Declination.

	1		2		3		4		5		6		7		8		9		10	
	D.	M.	D.	M.	D.	M	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	1
2	2	0	2	0	2	0	2	0	2	0	2	0	2	1	2	1	2	1	2	2
3	3	0	3	0	3	0	3	0	3	0	3	1	3	1	3	1	3	1	3	3
4	4	0	4	0	4	0	4	0	4	1	4	1	4	2	4	2	4	2	4	4
5	5	0	5	0	5	0	5	0	5	1	5	1	5	2	5	2	5	3	5	5
6	6	0	6	0	6	0	6	1	6	1	6	2	6	2	6	3	6	4	6	6
7	7	0	7	0	7	0	7	1	7	1	7	2	7	3	7	4	7	5	7	7
8	8	0	8	0	8	1	8	1	8	1	8	2	8	3	8	4	8	6	8	8
9	9	0	9	0	9	1	9	1	9	2	9	2	9	4	9	5	9	6	9	9
10	10	0	10	0	10	1	10	1	10	2	10	3	10	4	10	6	10	7	10	10
11	11	0	11	0	11	1	11	1	11	2	11	3	11	5	11	6	11	8	11	11
12	12	0	12	0	12	1	12	1	12	3	12	4	12	5	12	7	12	9	12	12
13	13	0	13	0	13	1	13	1	13	3	13	4	13	6	13	8	13	9	13	13
14	14	0	14	0	14	1	14	2	14	3	14	4	14	6	14	8	14	10	14	14
15	15	0	15	0	15	1	15	2	15	3	15	5	15	7	15	9	15	11	15	15
16	16	0	16	1	16	1	16	2	16	4	16	5	16	7	16	10	16	12	16	16
17	17	0	17	1	17	1	17	2	17	4	17	5	17	8	17	10	17	13	17	17
18	18	0	18	1	18	1	18	2	18	4	18	6	18	8	18	11	18	14	18	18
19	19	0	19	1	19	1	19	2	19	4	19	6	19	9	19	12	19	15	19	19
20	20	0	20	1	20	2	20	3	20	5	20	6	20	9	20	12	20	16	20	20
21	21	0	21	1	21	2	21	3	21	5	21	7	21	10	21	13	21	17	21	21
22	22	0	22	1	22	2	22	3	22	5	22	7	22	10	22	13	22	18	22	22
23	23	0	23	1	23	2	23	3	23	5	23	8	23	11	23	14	23	19	23	23
23.31	23	31	23	32	23	33	23	35	23	37	23	39	23	42	23	46	23	50	23	54

Degrees of Latitude.

Degrees of the Sun's Declination.

	11		12		13		14		15		16		17		18		19		20	
	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.
1	1	1	1	1	1	2	1	2	1	2	1	2	1	2	1	3	1	3	1	4
2	2	2	2	3	2	3	2	4	2	4	2	4	2	5	2	6	2	7	2	8
3	3	3	3	4	3	5	3	5	3	6	3	7	2	8	3	9	3	10	3	12
4	4	4	4	5	4	6	4	7	4	8	4	10	4	11	4	12	4	14	4	16
5	5	5	5	7	5	8	5	9	5	10	5	12	5	13	5	15	5	17	5	20
6	6	6	6	8	6	10	6	11	6	13	6	15	6	16	6	19	6	21	6	23
7	7	8	7	9	7	11	7	13	7	15	7	17	7	19	7	22	7	24	7	27
8	8	9	8	11	8	13	8	15	8	17	8	19	8	22	8	25	8	28	8	31
9	9	10	9	12	9	14	9	17	9	19	9	22	9	25	9	28	9	31	9	35
10	10	11	10	13	10	16	10	19	10	21	10	24	10	28	10	31	10	35	10	39
11	11	13	11	15	11	17	11	20	11	23	11	27	11	30	11	34	11	38	11	43
12	12	14	12	16	12	19	12	21	12	25	12	29	12	33	12	38	12	42	12	47
13	13	15	13	17	13	20	13	24	13	27	13	32	13	36	13	41	13	46	13	51
14	14	16	14	19	14	22	14	26	14	30	14	34	14	39	14	44	14	50	14	55
15	15	17	15	20	15	24	15	28	15	32	15	37	15	42	15	47	15	53	15	0
16	16	19	16	22	16	26	16	30	16	35	16	40	16	45	16	51	16	57	17	4
17	17	20	17	23	17	28	17	32	17	37	17	42	17	47	17	54	18	1	18	8
18	18	21	18	25	18	30	18	34	18	39	18	45	18	51	18	58	19	5	19	12
19	19	22	19	26	19	31	19	36	19	41	19	48	19	54	20	1	20	8	20	16
20	20	24	20	28	20	33	20	38	20	44	20	51	20	57	21	4	21	12	21	20
21	21	25	21	29	21	35	21	40	21	46	21	53	21	0	22	8	22	16	22	24
22	22	27	22	31	22	37	22	43	22	49	22	56	22	4	23	12	23	20	23	29
23	23	28	23	33	23	39	23	45	23	51	23	59	23	7	24	16	24	24	24	34
23.31	23	59	24	5	24	11	24	17	24	24	24	32	24	40	24	48	24	58	25	8

Degrees of Latitude.

Degrees of the Sun's Declination	21		22		23		24		25		26		27		28		29		30	
	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.
1	1	4	1	5	1	5	1	6	1	6	1	7	1	8	1	8	1	9	1	9
2	2	8	2	9	2	10	2	17	2	12	2	13	2	15	2	16	2	17	2	18
3	3	13	3	14	3	15	3	17	3	18	3	20	3	22	3	24	3	25	3	28
4	4	17	4	19	4	20	4	23	4	25	4	27	4	29	4	32	4	34	4	37
5	5	21	5	23	5	26	5	28	5	31	5	34	5	36	5	40	5	43	5	46
6	6	26	6	28	6	32	6	37	6	37	6	41	6	44	6	48	6	52	6	56
7	7	3	7	33	7	37	7	41	7	43	7	47	7	51	7	56	8	0	8	6
8	8	34	8	38	8	42	8	45	8	50	8	54	8	59	9	4	9	9	9	15
9	9	39	9	43	9	47	9	51	9	56	10	1	10	6	10	12	10	18	10	24
10	10	43	10	48	10	52	10	57	11	3	11	8	11	14	11	21	11	27	11	34
11	11	48	11	53	11	57	12	3	12	9	12	15	12	21	12	29	12	36	12	44
12	12	52	12	58	13	3	13	9	13	16	13	23	13	29	13	37	13	45	13	53
13	13	57	14	3	14	8	14	15	14	22	14	30	14	37	14	45	14	54	15	3
14	15	1	15	8	15	14	15	21	15	29	15	37	15	45	15	54	16	3	16	12
15	16	6	16	13	16	20	16	27	16	35	16	44	16	53	17	3	17	12	17	22
16	17	11	17	18	17	26	17	34	17	42	17	52	18	1	18	12	18	22	18	32
17	18	15	18	23	18	31	18	40	18	49	19	0	19	9	19	21	19	31	19	43
18	19	20	19	28	19	37	19	46	19	56	20	7	20	18	20	31	20	41	20	54
19	20	24	20	33	20	43	20	52	21	3	21	12	21	26	21	39	21	51	22	5
20	21	29	21	39	21	49	21	59	22	10	22	22	22	34	22	48	23	2	23	16
21	22	34	22	44	22	51	23	8	23	17	23	30	23	43	23	57	24	12	24	26
22	23	40	23	50	24	1	24	12	24	25	24	38	24	52	25	6	25	22	25	38
23	24	45	24	55	25	7	25	19	25	32	25	46	26	1	26	15	26	32	26	49
23.31	25	18	25	29	25	41	25	54	26	7	26	22	26	37	26	52	27	8	27	25

Degrees of Latitude.

Degrees of the Sun's Declination.	31		32		33		34		35		36		37		38		39		40	
	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.
1	1	10	1	10	1	11	1	12	1	13	1	14	1	15	1	16	1	17	1	18
2	2	19	2	21	2	23	2	25	2	26	2	29	2	30	2	32	2	34	2	36
3	3	29	3	33	3	35	3	38	3	40	3	44	3	45	3	49	3	52	3	55
4	4	39	4	44	4	45	4	50	4	53	4	58	5	0	5	5	5	8	5	13
5	5	50	5	54	5	58	6	2	6	6	6	11	6	16	6	21	6	26	6	32
6	7	0	7	5	7	9	7	14	7	20	7	25	7	31	7	37	7	43	7	50
7	8	10	8	16	8	21	8	27	8	33	8	40	8	47	8	54	9	1	9	9
8	9	20	9	27	9	33	9	39	9	47	9	54	10	2	10	10	10	19	10	28
9	10	31	10	39	10	45	10	52	11	0	11	9	11	17	11	27	12	37	11	47
10	11	41	11	48	11	59	12	5	12	14	12	24	12	33	12	43	13	55	13	6
11	12	52	13	0	13	9	13	18	13	28	13	39	13	50	14	0	14	13	14	25
12	14	2	14	11	14	21	14	32	14	41	14	54	15	6	15	18	15	31	15	44
13	15	13	15	23	15	33	15	45	15	56	16	9	16	22	16	35	16	50	17	4
14	16	23	16	35	16	45	16	59	17	1	17	24	17	38	17	52	18	8	18	24
15	17	34	17	46	17	58	18	12	18	25	18	40	18	55	19	10	19	27	19	45
16	18	44	18	58	19	11	19	26	19	40	19	55	20	11	20	28	20	46	21	5
17	19	56	20	10	20	24	20	39	20	55	21	11	21	28	21	47	22	6	22	26
18	21	7	21	22	21	37	21	53	22	10	22	27	22	46	22	5	23	25	23	47
19	22	19	22	35	22	51	23	7	23	25	23	44	24	4	24	24	24	46	25	9
20	23	31	23	47	24	4	24	22	24	40	25	0	25	22	25	43	26	7	26	31
21	24	43	25	0	25	17	25	37	25	56	26	17	26	40	27	3	27	28	27	53
22	25	55	26	13	26	31	26	52	27	12	27	35	27	58	28	23	28	49	29	1
23	27	7	27	26	27	46	28	7	28	29	28	53	29	18	29	44	30	11	30	40
23.31	27	43	28	3	28	24	28	45	29	8	29	32	29	58	30	25	30	53	31	[illegible]

Degrees of Latitude.

Degrees of the Sun's Declination.	41 D.	41 M.	42 D.	42 M.	43 D.	43 M.	44 D.	44 M.	45 D.	45 M.	46 D.	46 M.	47 D.	47 M.	48 D.	48 M.	49 D.	49 M.	50 D.	50 M.
1	1	20	1	21	1	22	1	23	1	25	1	26	1	28	1	29	1	31	1	33
2	2	40	2	41	2	44	2	46	2	50	2	53	2	56	2	59	3	3	3	6
3	3	58	4	2	4	6	4	10	4	15	4	19	4	24	4	29	4	34	4	46
4	5	18	5	23	5	28	5	34	5	40	5	45	5	52	5	59	6	6	6	14
5	6	38	6	44	6	51	6	58	7	5	7	12	7	21	7	29	7	38	7	48
6	7	57	8	5	8	12	8	21	8	30	8	38	8	49	8	59	9	10	9	22
7	9	18	9	26	9	35	9	45	9	55	10	6	10	18	10	30	10	42	10	56
8	10	37	10	47	10	58	11	9	11	21	11	33	11	47	12	0	12	44	12	31
9	11	58	12	9	12	21	12	34	12	47	13	1	13	16	13	31	13	48	14	5
10	13	18	13	31	13	44	13	58	14	13	14	27	14	45	15	2	15	21	15	40
11	14	39	14	53	15	7	15	23	15	39	15	55	16	15	16	34	16	54	17	16
12	16	0	16	10	16	30	16	48	17	6	17	25	17	45	18	6	18	28	18	52
13	17	21	17	38	17	54	18	13	18	33	18	54	19	16	19	39	20	3	20	29
14	18	42	19	0	19	18	19	39	20	0	20	23	20	47	21	12	21	38	22	6
15	20	4	20	23	20	43	21	5	21	28	21	53	22	18	22	45	23	14	23	44
16	21	25	21	46	22	8	22	32	22	56	23	23	23	50	24	20	24	51	25	23
17	22	48	23	10	23	34	23	59	24	25	24	53	25	23	25	55	26	28	27	3
18	24	10	24	34	24	59	25	20	25	55	26	25	26	57	27	31	28	6	28	44
19	25	33	25	59	26	26	26	54	27	25	27	57	28	32	29	7	29	45	30	25
20	26	57	27	24	27	53	28	23	28	56	29	30	30	7	30	45	31	25	32	9
21	28	21	28	50	29	19	29	53	30	27	31	3	31	42	32	23	33	6	33	53
22	29	46	30	16	30	48	31	23	32	0	32	37	33	19	34	3	34	48	35	40
23	31	11	31	43	32	17	32	55	33	32	34	13	34	57	35	43	36	34	37	26
23.31	31	54	32	27	33	2	33	41	34	20	35	2	35	48	36	34	37	26	38	20

Degrees of Latitude.

Degrees of the Sun's Declination.	51 D.	51 M.	52 D.	52 M.	53 D.	53 M.	54 D.	54 M.	55 D.	55 M.	56 D.	56 M.	57 D.	57 M.	58 D.	58 M.	59 D.	59 M.	60 D.	60 M.
1	1	35	1	37	1	39	1	42	1	45	1	47	1	50	1	53	1	56	2	0
2	3	10	3	15	3	20	3	24	3	29	3	34	3	40	3	46	3	53	4	0
3	4	46	4	52	4	59	5	6	5	14	5	22	5	31	5	40	5	50	6	0
4	6	22	6	30	6	39	6	49	6	59	7	10	7	22	7	34	7	47	8	1
5	7	58	8	8	8	19	8	32	8	45	8	58	9	13	9	28	9 11	45	10	2
6	9	34	9	46	10	0	10	15	10	30	10	47	11	4	11	23	13	43	12	4
7	11	10	11	25	11	41	11	58	12	16	12	35	12	56	13	18	15	41	14	6
8	12	47	13	4	13	22	13	41	14	2	14	24	14	48	15	14	57	41	16	10
9	14	24	14	43	15	4	15	26	15	48	16	15	16	42	17	10	19	41	18	14
10	16	1	16	23	16	46	17	11	17	37	18	6	18	36	19	8	21	42	20	19
11	17	39	18	3	18	29	18	57	19	26	19	57	20	31	21	6	23	45	22	26
12	19	18	19	44	20	13	20	43	21	15	21	50	22	26	23	6	25	49	24	34
13	20	58	21	28	21	57	22	30	23	5	23	43	24	23	25	7	28	54	26	44
14	22	38	23	6	23	42	24	18	24	57	25	38	25	22	27	10	30	1	28	56
15	24	17	24	51	25	28	26	7	26	49	27	34	28	22	29	14	32	10	31	10
16	25	59	26	36	27	16	27	58	28	43	29	32	30	24	31	21	34	22	33	27
17	27	41	28	21	29	4	29	50	30	39	31	31	32	28	33	29	36	35	35	47
18	29	25	30	8	30	54	31	44	32	36	33	33	34	34	35	40	39	52	38	10
19	31	9	31	56	32	45	33	38	34	35	35	36	36	43	37	54	41	13	40	37
20	32	55	33	45	34	39	35	35	36	36	37	42	38	53	40	12	44	37	43	10
21	34	48	35	36	36	33	37	33	38	40	39	51	41	9	42	34	46	1	45	47
22	36	32	37	29	38	31	39	37	40	46	42	4	43	27	44	59	49	40	48	32
23	38	23	39	24	40	20	41	40	42	56	44	20	45	50	47	30		21	51	24
23.31	39	20	40	21	41	29	42	43	44	2	45	30	47	2	48	49	50	44	51	53

The

The Deſcription, Conſtruction *and* Uſe *of this* Table.

I. *Its Deſcription.*

The Tables being in number Six, do each of them contain Eleven Columns, the firſt whereof towards the left hand contains the ſeveral degrees of the Sun's *Declination* from 1 deg. to 23 deg. 31 min. and at the head of each Column are the ſeveral degrees of Latitude from 1 deg. to 60 deg.

II. *Its Conſtruction.*

The *Latitude* of the Place and the *Declination* of the Sun being known, the *Canon*, *Analogy* or *Proportion* by which the *Table* is formed is This:

As the Sine Complement of the Latitude (ſuppoſe 43 deg. Latitude) 47 deg. 9.8641275

Is to the *Radius* 90 deg. 10.0000000

So is the Sine of the Declination (ſuppoſe 15 deg.) 19.4129962

To the Sine of the Amplitude 20 deg. 43 min. 9.5488687

					deg. m.
So likewiſe if the Latitude were	21	*And the Sun's Declination*	8	*The Amplitude would be found to be*	8 34
	35		17		20 55
	56		21		39 51

And here Note. (1.) If the Sun's *Declination* be *North*, the Sun's *Amplitude* of Riſing or Setting is towards the *North*, and the Sun *Riſes* between the *Eaſt* and the *North*; and *Sets* between the *Weſt* and the *North* ——But (2.) If the *Declination* be *South* the Sun Riſes between the *Eaſt* and the *South* and Sets between the *Weſt* and the *South*: (3.) When the Sun is in the *Equinoctial* and hath no degrees of *Declination* the Sun hath no degrees of *Amplitude*, but *Riſes* due *Eaſt*, and *Sets* due *Weſt*.

III. *Its Uſe.*

Seek the Latitude in the Head of the Table, and the Sun's Declination in the firſt Column, and in the Common Angle or Section, you have the *Amplitude*—Example, In the Latitude 15 deg. the Sun having 20 deg. of North *Declination* I would know his Amplitude:——Seek 15 degrees in the Head of the Table, and 20 in the firſt Column, and right againſt 20 and under 15 you ſhall find 20 deg. 44 min. and ſuch *Amplitude* ſhall the Sun have in the Latitude of 15 deg. when he hath 20 deg of *Declination*: And is *Northward* / *Southward* if the Declination be *North*, / *South*, according to the foregoing Note.

Here

A

T A B L E

SHEWING

What Declination the SUN ſhall have

WHEN THE

SUN Riſes or Sets

Upon any even Point or half Point

OF THE

COMPASS,

In any Latitude from the Equinoctial

to 60 Degrees.

The Point of the Compass upon which the Sun Rises and Sets.

Degrees of the Sun's Declination North.

Degrees of Latitude or of the Pole's Elevation.

☉ Rise ☉ Sets	East West	Half Point	E.byN. WbyN	Half Point	E.N.E. WNW	Half Point.	N.E.byE. N.W.byW	Half Point	N.East NWest	Half Point
60	0 0	2 49	5 36	8 21	11 2	13 38	16 8	18 30	20 42	22 44
59	0 0	2 54	5 46	8 36	11 22	14 3	16 37	19 4	21 22	23 27
58	0 0	2 59	5 56	8 51	11 42	14 28	17 7	19 30	22 0	
57	0 0	3 4	6 6	9 6	12 1	14 53	17 37	20 13	22 39	
56	0 0	3 9	6 16	9 21	12 22	15 18	18 6	20 47	23 18	
55	0 0	3 14	6 25	9 35	12 41	15 42	18 35	21 21		
54	0 0	3 18	6 35	9 50	13 0	16 5	19 3	21 54		
53	0 0	3 23	6 44	10 4	13 19	16 29	19 32	22 27		
52	0 0	3 28	6 54	10 18	13 37	16 52	20 0	23 0		
51	0 0	3 33	7 4	10 32	13 56	17 16	20 28	23 32		
50	0 0	3 37	7 12	10 45	14 14	17 30	20 55			
49	0 0	3 42	7 22	10 59	14 28	18 1	21 22			
48	0 0	3 46	7 30	11 12	14 51	18 24	21 49			
47	0 0	3 50	7 39	11 25	15 8	18 46	22 16			
46	0 0	3 55	7 47	11 38	15 25	19 7	22 42			
45	0 0	3 59	7 56	11 51	15 42	19 30	23 8			
44	0 0	4 3	8 4	12 3	15 50	19 50	23 32			
43	0 0	4 7	8 12	12 16	16 15	20 10				
42	0 0	4 11	8 20	12 28	16 31	20 31				
41	0 0	4 15	8 28	12 40	16 47	20 51				
40	0 0	4 19	8 36	12 51	17 3	21 10				
39	0 0	4 22	8 43	13 3	17 18	21 30				
38	0 0	4 26	8 50	13 14	17 33	21 49				
37	0 0	4 30	8 58	13 25	17 48	22 7				
36	0 0	4 33	9 5	13 35	18 2	22 25				
35	0 0	4 37	9 12	13 46	18 16	22 43				
34	0 0	4 40	9 18	13 56	18 30	23 1				
33	0 0	4 43	9 25	14 6	18 43	23 18				
32	0 0	4 46	9 31	14 16	18 55					
31	0 0	4 50	9 38	14 25	19 9					
30	0 0	4 52	9 44	14 34	19 21					
29	0 0	4 55	9 50	14 43	19 33					
28	0 0	4 58	9 55	14 51	19 45					
27	0 0	5 1	10 1	15 0	19 56					
26	0 0	5 4	10 6	15 8	20 7					
25	0 0	5 6	10 11	15 16	20 18					
24	0 0	5 9	10 16	15 23	20 28					
23	0 0	5 11	10 21	15 31	20 37					
22	0 0	5 13	10 25	15 38	20 45					
21	0 0	5 15	10 30	15 44	20 55					
20	0 0	5 17	10 34	15 51	21 5					
19	0 0	5 20	10 38	15 56	21 13					
18	0 0	5 22	10 42	16 2	21 20					
17	0 0	5 23	10 45	16 8	21 27					
16	0 0	5 25	10 49	16 12	21 34					
15	0 0	5 26	10 52	16 17	21 41					
14	0 0	5 28	10 55	16 22	21 47					
13	0 0	5 29	10 57	16 26	21 53					
12	0 0	5 30	11 0	16 30	21 58					
11	0 0	5 31	11 3	16 33	22 3					
10	0 0	5 33	11 5	16 37	22 7					
9	0 0	5 34	11 6	16 40	22 12					
8	0 0	5 35	11 8	16 43	22 15					
7	0 0	5 35	11 9	16 45	22 19					
6	0 0	5 36	11 11	16 47	22 21					
5	0 0	5 37	11 12	16 49	22 23					
4	0 0	5 37	11 14	16 50	22 26					
3	0 0	5 37	11 14	16 52	22 27					
2	0 0	5 38	11 14	16 52	22 29					
1	0 0	5 38	11 15	16 53	22 30					
☉ Rise ☉ Sets	East West	Half Point	E. by S. W.byS.	Half Point	E. S. E. W.SW.	Half Point	S. E. by E. S.W.by W.	Half Point	S. East S. West	Half Point

Degrees of the Sun's Declination South.

The Point of the Compass upon which the Sun Rises and Sets.

The Description, Construction and Use of this Table.

I. Its Description.

THe *Table* Consisteth of Eleven *Columns*, in the First of which towards the left hand are contained all degrees of *Latitude*, from 60 deg. down to the *Equinoctial*;——And at the head of the *Table* are so many *whole* and *half Points* of the *Compass*, as the *Sun* may *Rise* or *Set* upon in those *Latitudes* counted from the *East* or *West Northwards* ——And at the bottom of the *Table* are such *Points* and *half Points* of the *Compass*, as the *Sun* may *Rise* or *Set* upon in any of the forementioned *Latitudes* between the *East* or *West Points* and the *South*, as the Titles at the head and foot of the Table do express; And under them are the degrees of *Declination* that the *Sun* shall have when he *Rises* or *Sets* upon those *Points* of the *Compass*.

II. Its Construction.

If you would know what *Declination* the Sun shall have when he *Rises* upon the *E. by N.* and *Sets* upon the *W. by N.* Point of the *Compass* in any *Latitude* (suppose in the Latitude of 35 deg.) The *Analogie* or *Proportion* is,

As the *Radius* 90 deg.	10.0000000
To the Co-sine of the Latitude 55 deg.	9.9133645
So is the Sine of the Point of the Compass from the E. or W. *viz.* 11 deg. 15 min. (for E. by N.)	9.2902357
To the Sine of 9 deg. 12 min.	x9.2036002

And such *Declination* must the *Sun* have when he *Rises* upon the *E. by N.* and *Sets* upon *W. by N. Point* of the *Compass* in the Latitude of 35 deg.

III. Its Use.

Seek the *Latitude* in the first Column of the *Table* towards the left hand, and the *Point* or *half Point* of the *Compass* upon which the *Sun Rises* or *Sets* in the *head* or *bottom* of the *Table*, and in the common *Angle* or *Section* you shall have the *Declination* that the Sun then hath.

Example. What *Declination* shall the Sun have when he *Rises N. E. by E.* and *Sets N.W. by W.* in the Latitude of 48 deg. Look for 48 deg. in the first Column, and for *N. E. by E.* / *N.W. by W.* in the head of the Table, and under those *Points*, and against 48 deg. you shall find 21 deg. 49 min. for the *Declination* that the Sun shall have when he Rises *N. E. by E.* and Sets *N.W. by W.* in the *Latitude* of 48 deg. —And the like in any other *Latitude*.

A TABLE

A TABLE ſhewing what Declination the Sun ſhall have, when the Day is any Number of whole hours long in any Latitude.

The Difference between the Length of the Longeſt or Shorteſt Day, conſiſting of equal hours, and an Equinoctial Day of 12 hours.

Degrees of Latitude.	1		2		3		4		5		6	
	7	3	15	5	22	3	40	0	31	3	45	0
	☉ Decl.		☉ Decl.		☉ Decl.		☉ Decl.		☉ Decl.		☉ Decl.	
	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.
89	0	8	0	16	0	23	0	30	0	36	0	43
88	0	16	0	31	0	46	1	0	1	13	1	25
87	0	23	0	47	1	9	1	30	1	50	2	7
86	0	32	1	2	1	56	2	0	2	27	2	50
85	0	39	1	18	1	55	2	30	3	3	3	32
84	0	47	1	27	2	18	3	0	3	39	4	14
83	0	55	1	37	2	42	3	31	4	15	4	56
82	1	3	1	46	3	05	4	01	4	52	5	39
81	1	11	1	55	3	29	4	32	5	29	6	22
80	1	19	2	37	3	52	5	3	6	7	7	6
79	1	27	2	47	4	16	5	34	6	45	7	48
78	1	35	3	07	4	40	6	05	7	22	8	31
77	1	43	3	16	5	04	6	36	8	0	9	14
76	1	51	3	37	5	28	7	07	8	38	9	57
75	1	59	3	58	5	51	7	38	9	16	10	40
74	2	8	4	15	6	16	8	10	9	54	11	25
73	2	17	4	32	6	41	8	43	10	33	12	10
72	2	26	4	49	7	06	9	15	11	12	12	56
71	2	35	5	6	7	32	9	47	11	51	13	42
70	2	43	5	23	7	56	10	19	12	30	14	26
69	2	52	5	41	8	22	10	52	13	5	15	11
68	3	1	5	59	8	49	11	26	13	41	15	57
67	3	10	6	17	9	15	11	59	14	16	16	43
66	3	19	6	35	9	42	12	33	14	52	17	29
65	3	29	6	53	10	7	13	7	15	28	18	15
64	3	28	7	12	10	35	13	43	16	15	19	02
63	3	48	7	40	11	04	14	19	17	2	19	49
62	3	57	7	59	11	32	14	55	17	49	20	37
61	4	8	8	19	12	01	15	31	18	36	21	25
60	4	17	8	30	12	28	16	6	19	23	22	12
59	4	28	8	51	12	58	16	44	20	07	23	2
58	4	39	9	12	13	29	17	23	20	51	23	50
57	4	52	9	33	13	59	18	01	21	36		
56	5	1	9	54	14	30	18	40	22	21		
55	5	13	10	17	15	0	19	18	23	5		

The Difference between the Length of the Longest or Shortest Day, consisting of equal hours, and an Equinoctial Day of 12 hours.

Degrees of Latitude.	1		2		3		4		5		6	
	7	3	15	5	22	3	40	0	31	3	45	0
	☉ Decl.		☉ Decl.		☉ Decl.		☉ Decl.		☉ Decl.		☉ Decl.	
	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.
54	5	25	10	40	15	33	19	59	24	2		
53	5	38	11	04	16	7	20	40				
52	5	50	11	27	16	40	21	22				
51	6	2	11	51	17	14	22	04				
50	6	15	12	15	17	48	22	45				
49	6	30	12	42	18	26	23	27				
48	6	42	13	09	19	03	24	09				
47	6	56	13	37	19	40						
46	7	17	14	04	20	18						
45	7	26	14	31	20	57						
44	7	43	15	2	21	40						
43	8	00	15	33	22	23						
42	8	17	16	04	23	06						
41	8	34	16	36	23	23						
40	8	50	17	9								
39	9	10	17	47								
38	9	29	18	24								
37	9	49	19	02								
36	10	12	19	39								
35	10	34	20	17								
34	11	00	21	09								
33	11	26	22	01								
32	11	52	22	53								
31	12	18	23	44								
30	12	44										
29	13	15										
28	13	48										
27	14	22										
26	14	57										
25	15	39										
24	16	20										
23	17	5										
22	17	54										
21	18	46										
20	19	44										
19	20	46										
18	21	53										
17	23	7										
16	24	26										

The Deſcription Conſtruction an Uſe of this Table.

I. Its Deſcription.

THe *Table* conſiſts of *Seven Columns*, in the firſt whereof are all degrees of *Latitude* from the *Pole* to 16 degrees: And at the head of the *Table* is the *Difference* between the length of an *Equinoctial* day of 12 hours long, and the even hours of any other days length; in great Figures, and under them in ſmaller Figures, is the half difference of that length in degrées and minutes, and under them the *Declination* that the *Sun* ſhall then have when the day is ſo much longer or ſhorter than an *Equinoctial Day.*

II. Its Conſtruction.

If you would know what *Declination* the *Sun* ſhall have when the day is any number of even hours longer or ſhorter than an *Equinoctial Day* in any *Latitude*, Conſider the difference of thoſe Lengths, and an *Equinoctial Day* of 12 hours; and take the half thereof, which turn into Degrees and Minutes:-- As ſuppoſe I would know what *Declination* the *Sun* ſhall have when the day is either 15 deg. or 9 hours long in the Latitude of 54 deg.

Firſt, the difference between 9 or 15 hours and 12 hours (an *Equinoctial Day*) is 3 hours, the half whereof is 1 hour and a half, and that turned into time is 22 deg. 30 min.---Being thus prepared, the *Analogy* or *Proportion* to find the *Sun's Declination* at that time is,

As the *Radius* 90 deg.	10.0000000
Is to the *Sine* of half the diff. 1 hour 30 min. (*viz.* 22d. 30 m.)	9.5828397
So is the *Co-tangent* of the *Latitude* 36 deg.	9.8612610
To the *Tangent* of 15 deg. 33 min.	19.4441007

And ſuch *Declination* ſhall the *Sun* have, when the day is either 9 or 15 hours long in the *Latitude* of 54 deg.

III. Its Uſe.

Seek the *Latitude* in the *Firſt Column*, and the Difference between the day propoſed and an *Equinoctial Day* in the head of the *Table*, among the great *Figures*, and in the common *Section* you have the *Declination* deſired.

Example, What *Declination* ſhall the *Sun* have when the day is either 10 or 14 hours long in the *Latitude* of 76 deg.——The difference between 10 or 14 hours, and an *Equinoctial day* is 2 hours. Find 2 hours at the head of the *Table*, and under it, and againſt 76 the (*Latitude* found in the *Firſt Column*) you ſhall find 3 deg. 37. min. and ſuch *Declination* ſhall the *Sun* have when the day is either 10 or 14 hours long in the *Latitude* of 76 deg.

And ſo when the Day is either	11	13	*Hours long in the Latitude of*	20	*The Sun's Declination will be found to be*	19	44
	10	14		35		20	17
	9	15		48		19	03
	8	16		61		15	31
	7 or	17		70		12	30
	6	18		82		5	39

A TABLE *of Horizontal Spaces shewing the Distance of each* Hour-line *from the* Meridian : *upon all* Vertical *or* Horizontal *Plains, as also upon* Direct North *or* South Plains, *whether* Erect, Reclining *or* Inclining ; *Calculated to all Degrees of* Latitude (viz. *from* 00 *deg. to* 90 *deg.*) *that is, from the* Equinoctial *up to either of the* Poles.

Degrees of Latitude for Vertical or Horizontal Plains, or of the Stiles height above any Direct North or South upright Reclining or Inclining Plain.	XI. I.		X. II.		IX. III.		VIII. IV.		VII. V.		VI.	
	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.
1	0	16	0	34	1	0	1	44	3	44	90	00
2	0	32	1	09	2	0	3	27	7	25		
3	0	48	1	44	3	0	5	11	11	03		
4	1	05	2	19	4	0	6	54	14	36		
5	1	20	2	52	4	58	8	35	18	01		
6	1	36	3	27	5	58	10	16	21	19	90	00
7	1	52	4	03	6	57	11	15	24	27		
8	2	8	4	37	7	55	13	33	27	23		
9	2	23	5	09	8	54	15	10	30	17		
10	2	40	5	43	9	51	16	44	32	57		
11	2	55	6	17	10	48	18	17	35	27	90	00
12	3	11	6	51	11	45	19	48	37	49		
13	3	27	7	24	12	41	21	17	40	01		
14	3	43	7	57	13	36	22	44	42	04		
15	3	58	8	30	14	31	24	09	44	00		
16	4	13	9	02	15	25	25	31	45	49	90	00
17	4	29	9	35	16	26	26	52	47	26		
18	4	44	10	08	17	10	28	09	49	04		
19	4	59	10	39	18	02	29	25	50	33		
20	5	14	11	10	18	53	30	39	51	55		
21	5	29	11	41	19	44	31	50	53	09	90	00
22	5	44	12	13	20	32	32	58	54	21		
23	5	59	12	43	21	20	34	05	55	30		
24	6	13	13	13	22	08	35	10	56	37		
25	6	28	13	43	22	55	36	12	57	34		
26	6	42	14	12	23	40	37	13	58	34	90	00
27	6	55	14	41	24	25	38	11	59	27		
28	7	10	15	10	25	09	39	07	60	17		
29	7	24	15	40	25	52	40	02	61	04		
30	7	38	16	06	26	33	40	54	61	49		
31	7	05	16	34	27	15	41	44	62	30	90	00
32	8	05	17	01	27	55	42	30	63	11		
33	8	19	17	27	28	34	43	20	63	49		
34	8	31	17	54	29	13	44	05	64	24		
35	8	44	18	20	29	50	44	49	64	58		
36	8	57	18	45	30	27	45	31	65	30	90	00
37	9	10	19	09	31	02	46	12	66	10		
38	9	22	19	34	31	37	46	50	66	29		
39	9	24	19	58	32	11	47	28	66	56		
40	9	45	20	21	32	44	48	07	67	21		
41	9	57	20	44	33	16	48	39	67	47	90	00
42	10	10	20	07	33	46	49	12	68	11		
43	10	22	20	29	34	18	49	44	68	33		
44	10	32	21	51	34	47	50	10	68	54		
45	10	43	22	12	35	17	50	46	69	15		

A TABLE *of Horizontal Spaces shewing the Distance of each* Hour-line *from the* Meridian : *upon all* Vertical *or* Horizontal *Plains, as also upon* Direct North *or* South Plains, *whether* Erect, Reclining *or* Inclining: *Calculated to all Degrees of* Latitude (viz. *from* 00 *deg. to* 90 *deg.*) *that is, from the* Equinoctial *up to either of the* Poles.

Degrees of Latitude for Vertical or Horizontal Plains, or of the Stiles height above any Direct North or South upright Reclining or Inclining Plain.

	XI. I.		X. II.		IX. III.		VIII. IV.		VII. V.		VI.		
	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	
46	10	54	22	33	35	44	51	15	69	35	90	00	
47	11	05	22	53	36	11	51	42	69	53			
48	11	17	23	13	36	37	52	09	70	11			
49	11	25	23	33	37	03	52	35	70	28			
50	11	35	23	52	37	28	53	00	70	43			
51	11	45	24	09	37	52	53	24	70	59	90	00	
52	11	55	24	27	38	15	53	46	71	13			
53	12	05	24	43	38	37	54	18	71	28			
54	12	13	25	02	38	58	54	29	71	41			
55	12	22	25	18	39	19	54	49	71	54			
56	12	32	25	34	39	40	55	09	72	05	90	00	
57	12	40	25	50	39	59	55	28	72	17			
58	12	48	26	05	40	18	55	45	72	28			
59	12	56	26	20	40	36	56	03	72	38			
60	13	04	26	34	40	54	56	19	72	48			
61	13	11	26	47	41	10	56	34	72	58	90	00	
62	13	19	27	01	41	21	56	49	73	07			
63	13	26	27	13	41	42	57	03	73	15			
64	13	32	27	25	41	57	57	17	73	24			
65	13	39	27	37	42	15	57	30	73	32			
66	13	46	27	49	42	25	57	43	73	39	90	00	
67	13	51	27	59	42	38	57	54	73	46			
68	13	57	28	09	42	50	58	05	73	53			
69	14	03	28	19	43	02	58	16	73	59			
70	14	08	28	29	43	13	58	26	74	05			
71	14	13	28	37	43		58	35	74	11	90	00	
72	14	18	28	46	43	24	58	44	74	16			
73	14	22	28	54	43	36	58	53	74	20			
74	14	27	29	02	43	52	59	00	74	25			
75	14	30	29	07	44	00	59	07	74	30			
76	14	33	29	15	44	08	59	15	74	34	90	00	
77	14	37	29	21	44	14	59	22	74	37			
78	14	41	29	27	44	22	59	27	74	41			
79	14	44	29	32	44	28	59	32	74	44			
80	14	47	29	37	44	34	59	37	74	47			
81	14	49	29	41	44	37	59	40	74	49	90	00	
82	14	51	29	45	44	40	59	44	74	51			
83	14	53	29	49	44	44	59	47	74	53			
84	14	55	29	52	44	48	59	51	74	55			
85	14	56	29	54	44	53	59	54	74	57			
86	14	57	29	55	44	55	59	55	74	58	90	00	
87	14	58	29	56	44	57	59	56	74	58			
88	14	59	29	57	44	58	59	58	74	59			
89	14	59	29	50	44	59	59	59	74	59			
90	15	00	30	00	45	00	60	00	75	00			

The Description, Construction and Use of the foregoing Table.

THe *Table* consisteth of *Seven Columns*, in the first is contained whole degrees of *Latitude* from 1 to 90 degrees: And may be called the *Column* of *Latitudes*, *Co-Latitudes*, or of the *Stiles* height of any *Direct Horizontal*, *North* or *South Plain*, either *Erect* or *Reclining*.

In the other *Six Columns* you have the Space or Distance that each hour hath from the *Meridian*, when the *Stile* is any number of degrees to be elevated above the *Meridian* or *Substile*, as are the others of *Column Seventh*.

The Tables Construction.

It is known that 15 degrees of the *Equinoctial* is equal to one hour of time, then 30 is equal to Two hours, 45 to Three hours, *&c.* And then

As the *Radius* or *Sign* of 90 deg.
Is to the *Sine* of the *Latitude*, *Co-Latitude* or *Stiles* height 25 deg.
So is the *Tangent* of 15.
To the *Tangents* of 6 deg. 28 min.

	d.	m.	d.	m.	d.	m.	d.	m.
And so is the *Tangent* of	30	00.	45	00.	60	00.	75	00.
To the *Tangent* of	13	43.	22	25.	36	12.	57	34.

And such are the true hour distances for an *Horizontal*, *Vertical*, or any other *Direct Reclining Plain*, where the height of the *Pole* or *Stile* is found to be 25 deg.

The Use of this Table.

It serves principally for the ready making of *Horizontal Dials*, for to be obscurely described upon *Declining* or *Declining-Reclining Plains*, whereby the *Furniture*, (the *Tropicks* and *Parallels* of the 12 *Signs* and *Diurnal Arches* I mean) is more easily inserted upon such *Oblique Plains*: As in the former Tractates is sufficiently declared.

A TABLE shewing what Altitude the Sun shall have at every Hour, Half and Quarter of the Day, at his Entrance into every of the XII. Signs.

Calculated for the Latitude of London, 51 *deg.* 32 *min.*

Hours and Quarters	♋ Cancer ♋		Leo ♊ ♌ Gemini		Virgo ♉ ♍ Taurus		Libra ♈ ♎ Aries		Scorpio ♓ ♏ Pisces		Sagitt. ♒ ♐ Aquar.		♑ Capric. ♑	
	☉ Alt.		☉ Alt.		☉ Alt.		☉ Alt.		☉ Alt.		☉ Alt.		☉ Alt.	
	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.
XII.	61	59	58	41	49	59	38	28	26	57	18	15	14	57
1	61	49	58	34	49	52	38	22	26	52	18	10	14	52
2	61	23	58	8	49	32	38	01	26	37	17	56	14	50
3	60	40	57	27	48	57	37	36	26	12	17	34	14	18
XI. I.	59	42	56	33	48	10	36	56	25	37	17	03	13	48
1	58	29	55	25	47	11	36	05	24	53	16	24	13	09
2	57	04	54	06	46	01	35	04	24	01	15	36	12	23
3	55	29	52	34	44	40	33	55	22	59	14	19	11	29
X. II.	53	45	50	55	43	11	32	36	21	49	13	36	10	28
1	51	53	49	07	41	32	31	08	20	31	22	24	9	19
2	49	54	47	12	39	47	29	34	19	06	11	06	8	03
3	47	51	45	13	37	57	27	53	17	36	9	42	6	41
IX. III.	45	42	34	07	35	59	26	05	15	57	8	11	5	13
1	43	31	40	58	33	57	24	12	14	13	6	34	3	39
2	41	16	38	45	31	49	22	15	12	23	4	51	1	59
3	38	59	36	30	29	40	20	13	10	30	3	05	0	15
VIII.IV.	36	41	34	14	27	28	18	08	8	32	1	13		
1	34	23	31	56	25	13	15	58	6	31				
2	32	04	29	37	22	56	13	46	4	25				
3	29	43	27	16	20	37	11	32	2	16				
VII. V.	27	23	24	56	18	18	9	17	0	05				
1	25	04	22	37	15	59	6	58						
2	22	46	20	17	13	39	4	39						
3	20	28	17	57	11	16	2	20						
VI.	18	12	15	42	9	00	0	00						
1	15	58	14	00	6	44								
2	13	46	11	13	4	24								
3	11	37	9	01	2	08								
V. VII.	9	30	6	52										
1	7	25	4	46										
2	5	24	2	42										
3	3	27	0	43										
IV.VIII.	1	34												

The

The Deſcription, Uſe, *and* Conſtruction *of the foregoing* Table.

I. *Its Deſcription.*

THE *Table* conſiſteth of Eight *Columns:* The firſt whereof contains all *Hours*, *Halves* and *Quarters*, both *before* and *afternoon*; and in the other *Seven*, are the degrees and minutes of *Altitude* that the *Sun* hath at his entrance into any of the 12 *Signs:* as the *Titles* at the head of each *Column* do import.

II. *Its Uſe.*

Suppoſe I would know what Altitude the Sun ſhall have at Ten of the Clock, when he enters into either of the Signs *Virgo* ♍ or *Taurus* ♉. Look for *Virgo* or *Taurus* (which you ſhall find in the fourth Column) at the head of the Table, and under them and juſt againſt X. or II. a Clock (in the firſt Column) you ſhall find 43 deg. 11 min. And ſuch Altitude will the Sun have at *Ten* or *Two* a Clock when he enters into *Taurus* or *Virgo*, in the Latitude of 51 deg. 32 min. —— In like manner you ſhall find that

						deg.	*min.*
When the Sun enters into	*Cancer*	his Altitude at	XI.	I.	will be found to be	59	42
	Leo or *Gemini*		VIII. *or*	IV.		34	14
	Sagittarius or *Aquarius*		X.	II.		13	36

And the like for any other hour, half and quarter of the day, and at the entrance into any other of the *Signs*.

III. *Its Conſtruction.*

1. If the Sun be in the *Equinoctial*, that is, at his entrance into *Aries* ♈ or *Libra* ♎, and ſo have no *Declination*, the Sun's *Altitude* at any hour may be found by one Single *Proportion*, —— So the Sun being in the *Equinoctial*, and his *Altitude* at VIII. in the *Morning* or IV. in the *Afternoon* were required in the *Latitude* of 51 deg. 32 min. The *Proportion* to find the ſame is

As the Sine of 90	10.0000000
Is to the *Co-ſine* of the *Latitude* 38 deg. 28 min.	9.7941496
So is the Co-ſine of the hour from Noon 30 deg.	9.6989700
To the Sine of 18 deg. 8 min.	19.4931196

Which is the Sun's *Altitude* at *Four* or *Eight* of the Clock, when the Sun is in the beginning of *Aries* ♈ or *Libra* ♎, in the *Latitude* of 51 deg. 32 min.

This is the *Proportion* to find the *Altitude* at all *Hours*, when the Sun is in the *Equinoctial*, and hath no *Declination*; But when the Sun hath either *North* or *South Declination* from the *Equinoctial*, then there muſt be Two Operations to find the *Altitude* at all hours, except at VI a Clock, and at that hour One Operation will ſerve the turn.

Example, In the *Latitude* of 51 deg. 32 min. Let it be required to find the Sun's *Altitude* at *Six* a Clock when he enters into *Taurus* or *Virgo*, (his *Declination* then being 11 deg. 31 min.) The *Proportion* is,

As the *Radius* (or *Sine* of 90 deg.)	10.0000000
Is to the *Sine* of the Sun's *Declination*, 11 deg. 31 min.	9.3002758
So is the *Sine* of the *Latitude* 51 deg. 32 min.	9.8937452
To the Sine of 9 deg.	19.1940210

Which is the Sun's *Altitude* at Six a Clock.

For the *Altitude* of all other hours between XII and VI. (as at IV or VIII. a Clock) Two *Proportions* must be used;

(1.) As the *Co-sine* of the hour from the *Meridian* 30 deg.	9.6989700
To the *Radius* (or *Sine* of 90 deg.)	10.0000000
So is the *Tangent* of the *Latitude* 51 deg. 32 min.	10.0999135
To the *Tangent* of a *Fourth Arch* 68 deg. 30 min.	10.4007435

	deg.	*min.*	
The *Fourth Arch* is	68	20	from which the Sun having 11 deg.
31 min. of *Nor.Decl.* Subst.	11	31	and there remains
	56	46	for a *Fifth Arch.* Then Say,

(2.) As the *Sine* of the *Fourth Arch* 68 deg 20 min	9.9681781
To the *Co-sine* of the *Fifth Arch* 33 deg. 11 min	9.7382412
So is the *Sine* of the *Latitude* 51 deg. 32 min.	9.8937452
	19.6319864
To the Sine of 27 deg. 28 min.	9.6638083

And such *Altitude* shall the Sun have at Eight in the Morning, or Four in the Afternoon when he enters into *Taurus* ♉ or *Virgo* ♍.

When the Sun is in the *Southern Signs*, as *Libra* ♎, *Scorpio* ♏, *Sagittarius* ♐ *Capricorn* ♑, *Aquarius* ♒ or *Pisces* ♓, and hath *South Declination*:—— As suppose at X. or II. a Clock the Sun being in the beginning of *Sagitarius* ♐ or *Aquarius* ♒, (he having then 20 deg. 13 min. of *South Declination*:) Say,

(1.) As the *Co-sine* of the hour from the *Meridian* 60 deg.	9.0378506
To the *Radius* (or *Sine* of 90 deg.)	10.0000000
So is the *Tangent* of the *Latitude* 51 deg. 32 min.	10.0999135
To the *Tangent* of the *Fourth Arch* 55 deg. 27 min.	10.1620629

	deg.	*min.*	
To his *Fourth Arch*	55	27	(the Sun's *Decl.* being 20 d. 13 m. *South*) must be
added to it	20	13	
And the Sum will be	75	40	for a *Fifth Arch.* Then Say,

(2.) As the *Sine* of the *Fourth Arch* 55 deg. 27 min	9.9157330
To the *Co-sine* of the *Fifth Arch* 14 deg. 20 min.	9.3936852
So is the *Sine* of the *Latitude* 51 deg. 32 min.	9.8937452
	19.2874304
To the *Sine* of 13 deg. 36 min.	9.3716974

And

And ſuch *Altitude* ſhall the Sun have at Ten in the Forenoon or Two in the Afternoon, when the Sun is in the beginning of *Sagittarius* or *Aquarius*, and having 20 deg. 13 min. of *South Declination*.

For finding of the Sun's *Altitude* at any hour before Six in the Morning, or after Six at Night, the ſame *Proportion* foregoing will ſerve; Only note---That when the *Fourth Arch* is found, and the *Declination* of the Sun added to it (as it muſt always be) do exceed 90 deg. you muſt take the Complement thereof to 180 deg. for your *Fifth Arch*.

So the *Declination* being 20 deg. 13 min. *North*, And the *Altitude* at V. in the Morning or VII. at Night, were required, the *Altitude* will be found to be 6 deg. 52 min. For,

(1.) As the *Co-ſine* of the hour from the *Meridian* 15 deg.	9.4129962
To the *Radius* 90 deg.	10.0000000
So is the *Tangent* of the *Latitude* 51 deg. 32 min.	10.0999135
To the Tangent of the *Fourth Arch* 78 deg. 22 min.	10.6869173

	deg.	min.	
The *Fourth Arch* being	78	22	
To which add the Sun's *Declinat.*	20	13	
the Sum is	98	35	
Whoſe Complement to 180 deg. is	81	25	is the *Fifth Arch*. Then,

(2.) As the *Sine* of the *Fourth Arch* 78 deg. 22 min.	9.9909859
To the *Co-ſine* of the *Fifth Arch* 8 deg. 35 min.	9.1739077
So is the *Sine* of the *Latitude* 51 deg. 32 min.	9.8937452
	19.0676529
To the *Tangent* 6 deg. 52 min.	9.0766670

Which is the Sun's *Altitude* at V. in the Morning, or VII in the Evening.

A TABLE *shewing what Azimuth from the South, the Sun shall have at every Hour, Half and Quarter of the Day, at his Entrance into every of the XII. Signs.*

Calculated for the Latitude of London, 51 *deg.* 32 *min.*

Hours and Quarters	♋ Cancer ♋	*Leo* ♊ ♌ *Gemini*	*Virgo* ♉ ♍ *Taurus*	*Libra* ♈ ♎ *Aries*	*Scorpio* ♓ ♏ *Pisces*	*Sagitt.* ♒ ♐ *Aquar.*	♑ *Capric.* ♑
	⊙ *Azi.*	⊙ *Azi.*	⊙ *Azi.*	⊙ *Azi.*	⊙ *Azi.*	⊙ *Azi.*	⊙ *Azi.*
	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.
XII.	00 00	0 00	0 00	0 00	0 00	0 00	0 00
1	7 10	5 53	5 37	4 55	3 54	3 53	3 52
2	14 22	13 24	11 10	9 40	7 57	7 40	7 10
3	21 27	19 53	16 44	14 13	12 11	11 10	10 37
XI. I.	27 56	26 00	22 13	18 52	16 22	14 45	14 13
1	34 14	32 01	27 32	23 22	20 15	18 17	17 38
2	40 12	37 40	32 41	27 41	24 06	21 53	20 59
3	45 39	43 04	37 32	32 08	29 44	26 30	24 25
X. II.	50 51	47 57	42 05	36 24	31 50	28 52	27 47
1	55 31	52 41	47 04	40 30	35 35	32 18	31 00
2	61 43	57 11	50 51	44 26	39 10	35 39	34 17
3	64 11	61 18	50 33	48 13	42 36	38 50	37 34
IX. III.	68 10	65 16	58 47	51 56	46 02	42 04	40 38
1	71 52	69 56	62 33	55 33	49 25	45 16	43 40
2	75 26	72 37	66 10	58 59	52 43	48 21	46 42
3	78 48	76 05	69 38	62 22	55 59	51 22	49 40
VIII. IV.	82 00	79 30	72 57	65 40	59 00	54 22	
1	85 08	82 42	76 12	68 53	62 08		
2	88 10	85 38	79 23	72 06	65 12		
3	91 09	87 50	82 28	75 07	68 12		
VII. V.	94 15	91 34	85 30	78 06	71 10		
1	96 51	94 25	88 27	81 09			
2	99 38	97 16	91 23	84 06			
3	102 55	100 07	94 22	87 04			
VI.	105 08	102 54	97 12				
1	107 52	104 58	100 02				
2	110 36	108 26	103 00				
3	113 18	111 14	105 54				
V. VII.	116 03	114 03					
1	118 50	116 54					
2	121 41	119 47					
3	124 29	122 37					
IV. VIII.	127 24						

The Description, Use, *and* Construction *of the foregoing* Table.

I. *Its Description*

THis *Table* (as that foregoing) consisteth of *Eight Columns*; The First contains all the *Hours*, *Halves* and *Quarters* both before and afternoon; And in the other are the Degrees and Minutes of the Sun's *Azimuth* from the *South* at the Sun's entrance into every of the 12 *Signs*, as the Titles at the top thereof do signifie.

II. *Its Use.*

If you would know what *Azimuth*, from the *South*, the Sun shall have at IX. or III. of the Clock, when the Sun enters into *Virgo* ♍ or *Taurus* ♉ —— Look for *Virgo* and *Taurus* at the Head of the *Table*, and under it (against IX. and III. a Clock) in the First Column, you shall find 58 deg. 47 min. And such *Azimuth* shall the Sun have from the South part of the *Meridian*. So likewise.

							d.	m.
When the Sun enters into	*Cancer*,	the *Azimuth* at	X.	or	II.	will be found to be	50	51
	Leo or *Gemini*,		IX.		III.		65	16
	Scorpio or *Pisces*,		VII.		V.		71	10
	Taurus or *Virgo*,		XI.		I.		72	13

III. *Its Construction*

If it were required to find what *Azimuth* the Sun shall have from the South part of the *Meridian*, at VIII or IV of the Clock at, the Sun's entrance into *Leo* or *Gemini* (he having then 20 deg. 13 min. of *North Declination*) —— You must (by the foregoing *Table*) find what *Altitude* the Sun (at that time) hath, which will be 34 deg. 14 min. which known, the *Proportion* will be

As the *Co-sine* of the *Altitude* 55 deg. 46 min.	9.9173760
To the *Sine* of the hour from the *Meridian* 60 deg.	9.9375316
So the *Co-sine* of the *Declination* 69 deg. 47 min.	9.9723845
	19.9099161
To the *Sine* of 79 deg. 30. min.	9.9926501

And such is the Sun's *Azimuth* from the South part of the *Meridian*.

A TABLE *of the Sun's* Altitude *at all Hours of the Day, at the Sun's Entrance into any of the* XII. Signs, *and at every Tenth Degree thereof.*

Calculated for the Latitude *of* 50 *deg. viz.*

Hours Beforen. S. D.	Aftern. S. D.	XII. D. M.	XI. I. D. M.	X. II. D. M.	IX. III. D. M.	VIII. IV. D. M.	VII. V. D. M.	VI. D. M.	V. VII. D. M.	IV. VIII. D. M.
♋ 0	♋ 0	63 30	61 1	54 39	46 13	36 52	27 14	17 46	8 46	0 35
20	10	63 7	60 39	54 20	45 56	36 35	26 58	17 29	8 28	0 16
10	20	62 0	59 36	53 24	45 5	35 47	26 9	16 39	7 36	
♊ 0	♌ 0	60 12	57 54	51 52	43 41	34 27	24 51	15 19	6 12	
20	10	57 46	55 34	49 48	41 47	32 40	23 5	13 30	4 18	
10	20	54 51	52 46	47 14	39 27	30 27	20 55	11 18	2 1	
♉ 0	♐ 0	51 30	49 33	44 16	36 43	27 52	18 24	8 46		
20	10	47 49	46 0	40 58	33 40	25 0	15 36	5 59		
10	20	43 58	43 58	37 28	30 26	21 56	12 39	3 2		
♈ 0	♎ 0	40 0	38 23	33 50	27 43	18 45	9 35			
20	10	36 2	34 30	30 9	23 36	15 31	6 29			
10	20	32 11	30 43	26 34	20 15	12 22	3 29			
♓ 0	♏ 0	28 30	27 8	23 9	17 2	9 21	0 36			
20	10	25 9	23 50	20 0	14 5	6 35				
10	20	22 14	20 58	17 15	11 30	4 10				
♒ 0	♐ 0	19 49	18 34	14 59	9 21	2 9				
20	10	18 0	16 48	13 17	7 45	0 40				
10	20	16 53	15 42	12 14	6 46					
♑ 0		16 30	15 19	11 52	6 25					

A TABLE *of the Sun's* Azimuth *for every Hour in the beginning of each* Sign, *for the Latitude of* 50 *Degrees.*

		XI. I. D. M.	X. II. D. M.	IX. III. D. M.	VIII. IV. D. M.	VII. V. D. M.	VI. D. M.	IV. VII. D. M.	IV. VIII. D. M.
	♋	60 41	37 34	20 23	6 48	4 N48	15 37	26 18	37 24
♌	♊	62 48	40 32	23 23	9 40	3 16	13 17	24 12	
♍	♉	66 57	46 49	30 19	16 15	1 S 59	7 N27		
♎	♈	70 43	52 59	37 17	23 51	12 36			
♏	♓	73 26	57 48	43 33	30 40	18 45			
♐	♒	75 9	60 56	47 43	35 34				
	♑	75 45	62 3	49 14					

A TABLE *of the Sun's* Altitude *at all Hours of the Day, at the Sun's Entrance into any of the* XII. Signs, *and at every Tenth Degree thereof.*

Calculated for the Latitude *of* 52 *deg.*

Hours Beforen.	Hours Aftern.	XII.	XI. I.	X. II.	IX. III.	VIII. IV.	VII. V.	VI.	V. VII.	IV. VIII.
S. D.	S. D.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.
♋ 0	♋ 0	61 30	59 58	53 21	45 51	36 36	27 23	18 19	9 39	1 48
10	10	61 7	58 53	53 5	45 11	36 18	27 6	18 0	9 21	1 29
20	20	60 0	57 50	52 7	44 18	35 28	26 16	17 9	8 27	1 32
♊ 0	♌ 0	58 13	56 6	50 33	42 52	34 1	24 57	15 48	7 3	
10	10	55 47	53 47	48 25	40 54	32 14	23 5	13 54	5 5	
20	20	52 52	50 58	46 49	38 30	29 57	20 50	11 38	2 44	
♉ 0	♍ 0	49 30	47 43	42 48	35 42	27 18	18 18	9 2	0 3	
10	10	45 51	44 9	39 27	32 35	24 20	15 21	6 9		
20	20	42 0	40 23	35 54	29 16	21 12	12 26	3 8		
♈ 0	♎ 0	38 0	36 29	32 13	25 48	17 6	9 10			
10	10	34 2	32 36	28 21	22 19	14 38	6 0			
20	20	30 11	28 49	24 54	18 55	11 24	2 54			
♓ 0	♏ 0	26 30	25 12	21 27	15 31	8 19	0 56			
10	10	23 9	21 55	18 17	12 39	5 30				
20	20	22 41	19 2	15 31	10 2	3 2				
♒ 0	♐ 0	17 49	16 38	13 14	7 52	0 59				
10	10	16 0	14 52	11 31	6 15					
20	20	14 53	13 46	10 28	5 15					
♑ 0		14 30	13 21	10 3	4 51					

A TABLE *of the Sun's* Azimuth *for every Hour in the beginning of each* Sign, *for the Latitude of* 52 *Degrees.*

		XI. I.	X. II.	IX. III.	VIII. IV.	VII. V.	VI.	V. VII.	IV. VIII.
		D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.
♋		62 21	39 43	22 19	8 S 18	3 N 46	14 58	26 0	37 22
♌	♊	64 11	42 23	25 6	10 S 58	1 N 16	12 44	24 0	
♍	♉	67 52	48 6	31 26	17 14	4 S 39	7 N 7	18 49	
♎	♈	71 13	53 46	38 15	24 28	11 55			
♏	♓	73 43	58 14	43 59	30 56				
♐	♒	75 19	61 10	47 56	35 36				
♑		75 52	62 14	49 23					

A TABLE *of the Sun's* Altitude *at all Hours of the Day, at the Sun's Entrance into any of the* XII. Signs, *and at every Tenth Degree thereof.*

Calculated for the Latitude *of* 52 *deg.* 30 *min.*

Hours Before n.		Aftern.		XII.		XI. I.		X. II.		IX. III.		IV. VIII.		VII. V.		VI.		V. VII.		IV. VIII.	
S.	D.	S.	D.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.
♋	0	♋	0	61	0	58	50	53	7	45	20	36	33	27	27	18	27	9	55	2	9
	20		10	60	39	58	30	52	49	45	3	36	17	27	11	18	10	9	37	1	50
	10		20	59	32	57	26	51	50	44	9	35	36	26	20	17	19	8	43	0	53
♊	0	♌	0	57	43	55	41	50	15	42	42	34	2	24	58	15	55		15		
	20		10	55	18	53	22	48	7	40	43	32	9	23	7	14	2	5	18		
	10		20	52	22	52	32	45	29	38	17	29	51	20	51	11	45	2	55		
♉	0	♐	0	49	1	47	17	42	27	35	28	27	10	18	14	9	7	0	12		
	20		10	45	21	43	42	39	5	32	20	24	12	15	20	6	13				
	10		20	41	28	39	54	35	30	28	58	21	0	12	15	3	9				
♈	0	♎	0	37	30	36	1	31	49	25	30	17	43	9	4						
	20		10	33	32	32	8	28	6	22	0	14	24	5	52						
	10		20	29	39	28	19	24	27	18	33	11	8	2	44						
♓	0	♏	0	25	59	24	42	20	59	15	16	8	2								
	20		10	22	39	21	24	17	49	12	16	5	12								
	10		20	19	42	18	30	15	2	9	38	2	42								
♒	0	♐	0	17	17	16	7	12	44	7	27	0	39								
	20		10	15	28	14	20	11	9	5	49										
	10		20	14	21	13	14	9	57	4	44										
♑	0			14	0	12	53	9	36	4	29										

A TABLE

A TABLE *of the Sun's* Altitude *at all Hours of the Day, at the Sun's Entrance into any of the* XII. Signs, *and at every Tenth Degree thereof.*

Calculated for the Latitude *of* 54 *deg.*

Hours Beforen. S.	D.	Aftern. S.	D.	XII. D.	M.	XI. I. D.	M.	X. II. D.	M.	IX. III. D.	M.	VIII. IV. D.	M.	VII. V. D.	M.	VI. D.	M.	V. VII. D.	M.	IV. VIII. D.	M.
♋	0	♋	0	59	30	57	28	52	6	44	42	36	17	27	30	18	48	10	31	3	1
	20		10	59	7	57	6	51	46	44	23	35	59	27	12	18	30	10	13	2	41
	10		20	58	0	56	2	50	47	43	29	35	7	26	20	17	33	9	18	1	43
♊	0	♌	0	56	12	54	18	49	11	42	0	33	42	24	57	16	12	7	49	0	11
	20		10	53	46	51	57	47	0	39	59	31	46	23	3	14	17	5	50		
	10		20	50	51	49	6	44	22	37	30	29	25	20	45	11	57	3	27		
♉	0	♍	0	47	30	45	51	41	18	34	38	26	41	18	4	9	16	0	48		
	20		10	43	49	42	16	37	54	31	27	23	39	15	7	6	19				
	10		20	39	58	38	29	34	19	28	4	20	26	11	59	3	12				
♈	0	♎	0	36	0	34	36	30	36	24	34	17	5	8	45						
	20		10	32	2	30	42	26	52	22	1	13	43	3	30						
	10		20	28	11	26	54	23	13	17	34	10	26	2	20						
♓	0	♏	0	24	31	23	17	19	45	14	15	7	18								
	20		10	21	9	19	59	16	33	11	13	4	55								
	10		20	18	14	17	6	13	47	8	35	1	24								
♒	0	♐	0	15	49	14	43	11	28	6	23										
	20		10	14	0	12	55	9	45	4	45										
	10		20	12	53	11	46	8	42	3	44										
♑	0			12	30	11	27	8	19	3	23										

A TABLE *of the Sun's* Azimuth *for every Hour in the beginning of each* Sign, *for the Latitude of* 54 *Degrees.*

		XI. I. D.	M.	X. II. D.	M.	IX. III. D.	M.	VIII. IV. D.	M.	VII. V. D.	M.	VI. D.	M.	IV. VII. D.	M.	V. VIII. D.	M.
♋		63	49	41	42	24	9	9	47	2	N42	14	19	25	41	37	18
♌	♊	65	24	44	6	26	44	12	17	0	1	12	10	23	46	35	37
♍	♉	68	39	49	17	32	38	18	14	5 S	20	6 N	49	18	47		
♎	♈	71	40	54	29	38	58	25	2	12	14						
♏	♓	73	58	58	38	44	22	31	10								
♐	♒	75	27	61	23	48	6										
♑		75	59	62	23	49	29										

A TABLE *shewing what* Altitude *the* Sun *shall have at every* Hour *of the* Day, *when he is in the* Tropick *of* Cancer, *the* Equinoctial *and* Tropick *of* Capricorn.

Calculated from 36 to 66 ½ deg. of Latitude.

Hours	{ *Beforenoon* / *Afternoon*	XII.		XI. I.		X. II.		IX. III.		IV. VIII.		VII. V.		VI.	
Degrees of Latitude.		D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.
36	♋	77	30	72	0	61	16	49	22	37	15	25	14	13	33
	♈ ♎	54	0	51	24	44	29	34	54	23	52	12	5	0	0
	♑	30	30	28	50	24	5	16	52	7	51				
37	♋	76	30	71	20	60	57	49	17	37	19	25	26	13	53
	♈ ♎	53	0	50	19	43	46	34	23	23	32	11	56		
	♑	29	30	27	52	23	13	16	8	7	15				
38	♋	75	30	70	39	60	37	49	9	37	22	25	38	14	13
	♈ ♎	52	0	49	34	43	2	33	52	23	12	11	46		
	♑	28	30	26	54	22	21	15	24	6	39				
39	♋	74	30	69	57	60	15	49	1	37	24	25	49	14	32
	♈ ♎	51	0	48	39	42	18	33	20	22	52	11	36		
	♑	27	30	25	57	21	29	14	39	6	3				
40	♋	73	30	59	12	59	51	48	51	37	29	25	59	14	51
	♈ ♎	50	0	47	44	41	34	32	48	22	31	11	26		
	♑	26	30	24	50	20	37	14	55	5	27				
41	♋	72	30	68	27	59	26	48	41	37	25	26	9	15	10
	♈ ♎	49	0	46	47	40	49	32	15	22	10	11	16		
	♑	25	30	24	1	19	45	13	10	4	51				
42	♋	71	30	67	41	58	59	48	29	37	25	26	18	15	28
	♈ ♎	48	0	45	52	40	4	31	42	21	49	11	5		
	♑	24	30	23	3	18	52	12	45	4	14				
43	♋	70	30	66	54	58	31	48	16	37	24	26	31	15	47
	♈ ♎	47	0	44	57	39	18	31	8	21	27	10	55		
	♑	23	30	22	5	18	0	11	49	3	38				
44	♋	69	30	66	5	58	2	48	2	37	22	26	36	16	5
	♈ ♎	46	0	44	1	38	32	30	34	21	3	10	44		
	♑	22	30	21	7	17	7	10	55	3	2				
45	♋	68	30	65	17	57	31	47	46	37	19	26	44	16	22
	♈ ♎	45	0	43	5	37	46	30	0	20	42	10	33		
	♑	21	30	20	9	16	14	10	10	2	25				
46	♋	67	30	64	27	36	59	47	30	37	15	26	51	16	34
	♈ ♎	44	0	42	9	36	59	29	22	20	19	10	21		
	♑	20	30	19	11	15	22	9	25	1	49				
47	♋	66	30	63	36	56	26	47	13	37	11	26	58	16	57
	♈ ♎	43	0	41	12	36	12	28	50	19	56	10	10		
	♑	19	30	18	13	14	29	8	40	1	13				
48	♋	65	30	62	45	55	52	46	54	37	6	27	4	17	14
	♈ ♎	42	0	40	16	35	25	28	18	19	33	9	58		
	♑	18	30	16	16	12	43	7	9						
49	♋	64	30	61	53	55	20	46	36	37	00	27	15	17	31
	♈ ♎	41	0	39	6	34	37	27	40	19	9	9	35		
	♑	17	30	15	47	12	6	6	46						
50	♋	63	30	61	2	54	41	46	15	36	53	27	20	17	47
	♈ ♎	40	0	38	23	33	50	27	2	18	45	9	22		
	♑	16	30	15	18	11	30	6	24	⊙ Set					

Degrees of Latitude.	Hours { Beforenoon / Afternoon	XII. D.	XII. M.	XI. / I. D.	XI. / I. M.	X. / II. D.	X. / II. M.	IX. / III. D.	IX. / III. M.	VIII. / IV. D.	VIII. / IV. M.	VII. / V. D.	VII. / V. M.	VI. D.	VI. M.
51	♋	62	30	60	9	54	4	45	53	35	46	27	20	18	3
	♈ ♎	39	0	87	26	33	2	26	25	18	20	9	22		
	♑	15	30	14	20	10	57	5	38						
52	♋	61	30	59	16	53	26	45	31	36	37	27	25	18	19
	♈ ♎	38	0	36	29	32	13	25	48	17	56	9	10		
	♑	14	30	13	12	10	4	4	53						
53	♋	60	30	58	23	52	47	45	8	36	28	27	28	18	34
	♈ ♎	37	0	35	33	31	25	25	11	17	31	8	58		
	♑	13	30	12	24	9	11	4	7						
54	♋	59	30	57	29	52	8	44	44	36	14	27	31	18	49
	♈ ♎	30	0	34	36	30	36	24	34	17	5	8	45		
	♑	12	30	11	25	8	18	3	21						
55	♋	53	30	56	35	51	28	44	19	36	8	27	34	19	4
	♈ ♎	35	0	33	39	29	47	23	56	16	40	8	32		
	♑	11	30	10	27	7	14	2	36						
56	♋	57	30	55	41	50	46	43	53	35	57	27	36	19	18
	♈ ♎	34	0	32	42	28	58	23	17	16	14	8	19		
	♑	10	30	9	29	6	31	1	50						
57	♋	56	30	54	46	50	5	43	26	35	45	27	38	19	32
	♈ ♎	33	0	31	44	28	9	22	39	15	48	8	6		
	♑	9	30	8	31	5	30	1	4						
58	♋	55	30	53	52	49	23	42	59	35	32	27	39	19	45
	♈ ♎	32	0	30	47	27	19	22	0	15	22	7	53		
	♑	8	30	7	33	4	45	0	19						
59	♋	51	30	52	57	48	45	42	31	35	18	27	40	19	59
	♈ ♎	31	0	29	50	26	29	21	21	14	55	7	40		
	♑	7	30	6	34	3	51								
60	♋	53	30	52	1	47	56	42	2	35	4	27	39	20	12
	♈ ♎	30	0	28	53	25	40	20	42	14	29	7	26		
	♑	6	30	5	36	3	58								
61	♋	52	30	51	6	47	12	41	32	34	49	27	38	20	25
	♈ ♎	29	0	27	55	24	55	20	3	14	2	7	13		
	♑	5	30	4	38	2	5								
62	♋	51	30	50	10	46	28	41	2	34	34	27	37	20	37
	♈ ♎	28	0	26	58	23	59	19	23	13	35	6	59		
	♑	4	30	3	39	1	11								
63	♋	50	30	44	9	45	43	40	3	34	18	27	35	20	49
	♈ ♎	27	0	26	51	23	9	18	44	13	7	6	45		
	♑	3	30	2	41	0	18								
64	♋	49	30	48	18	44	57	39	59	34	1	27	33	21	0
	♈ ♎	28	0	25	3	22	19	18	3	12	40	6	31		
	♑	2	30	1	43										
65	♋	48	30	47	22	44	11	39	27	33	43	27	30	21	14
	♈ ♎	25	0	24	5	21	28	17	23	12	12	6	17		
	♑	1	30	0	45										
66	♋	47	30	46	26	43	25	38	54	33	25	27	26	21	22
	♈ ♎	24	0	23	8	20	38	16	43	11	44	6	3		
	♑	0	30												
66½	♋	47	0	45	58	43	2	38	38	33	16	27	24	21	27
	♈ ♎	23	30	22	39	20	12	16	23	11	30	5	29		
	♑	0	0												

A TABLE *shewing what* Azimuth *the Sun shall have forom the* East *or* West, *at all* Hours *of the* Day:

Calculated from 36 *to* 66 ½ *deg. of* Latitude.

Hours: Beforenoon / Afternoon		XII.		XI. / I.		X. / II.		IX. / III.		VIII. / IV.		VII. / V.		VI.	
		☉ Azi.		☉ Azi.		☉ Azi.		☉ Azi.		☉ Azi.		☉ Azi.		☉ Azi.	
Degrees of Latitude.		D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.	D.	M.
36	♋	90	0	39	55	17	32	5	7	3 N	50	11	40	19	21
	♈ ♎	90	0	65	29	45	30	30	26	18	44	8	57		
	♑	90	0	74	17	59	59	47	19	36	41				
37	♋	90	0	42	14	19	15	6	17	2 N	59	11	12	19	7
	♈ ♎	90	0	66	0	46	11	31	2	19	10	9	7		
	♑	90	0	74	25	60	3	47	31	36	47				
38	♋	90	0	44	20	20	57	7	33	2 N	7	10	42	18	52
	♈ ♎	90	0	66	29	46	50	31	37	19	34	9	22		
	♑	90	0	74	33	60	16	47	45	36	53				
39	♋	90	0	46	16	22	35	8	45	1 N	16	10	13	18	38
	♈ ♎	90	0	66	56	47	28	32	11	19	58	9	34		
	♑	90	0	74	41	60	28	47	54	36	59				
40	♋	90	0	48	5	24	7	9	49	9	26	9	46	18	23
	♈ ♎	90	0	67	22	48	4	32	44	20	22	9	46		
	♑	90	0	74	49	60	39	48	4	37	7				
41	♋	90	0	49	46	25	43	10	57	0	24	9	17	18	8
	♈ ♎	90	0	67	47	48	39	33	16	20	45	9	58		
	♑	90	0	74	56	60	50	48	13	37	8				
42	♋	90	0	51	20	27	10	12	4	0	24	8	49	17	53
	♈ ♎	90	0	67	52	49	12	33	47	21	7	10	10		
	♑	90	0	75	3	61	0	48	23	37	12				
43	♋	90	0	52	49	28	37	13	5	1	16	8	19	17	37
	♈ ♎	90	0	68	33	49	45	34	18	21	29	10	21		
	♑	90	0	75	9	60	10	48	0	37	15				
44	♋	90	0	54	12	30	4	14	13	2	27	7	47	17	20
	♈ ♎	90	0	68	54	50	16	34	47	21	51	10	32		
	♒	90	0	75	15	61	19	48	39	37	18				
45	♋	90	0	55	29	31	26	15	16	2	59	7	17	17	4
	♈ ♎	90	0	69	15	50	46	35	16	22	13	10	43		
	♑	90	0	75	22	61	28	48	46	37	20				
46	♋	90	0	56	39	32	43	16	18	3	50	5	48	16	47
	♈ ♎	90	0	69	34	51	15	35	44	22	34	10	55		
	♑	90	0	75	26	61	36	48	53	37	22				
47	♋	90	0	57	45	33	59	17	23	4	32	6	18	16	29
	♈ ♎	90	0	69	53	51	43	36	11	22	54	11	5		
	♑	90	0	75	31	61	43	49	0	37	29				
48	♋	90	0	58	48	35	15	18	23	5	24	5	49	16	12
	♈ ♎	90	0	70	10	52	9	36	37	23	13	11	16		
	♑	90	0	75	36	61	50	49	5						
49	♋	90	0	59	43	36	20	19	17	6	6	5	16	15	54
	♈ ♎	90	0	70	27	52	35	37	2	23	22	11	26		
	♑	90	0	75	41	61	57	49	10						
50	♋	90	0	60	38	37	26	20	12	6	49	4 N	53	15	3
	♈ ♎	90	0	70	44	53	00	37	28	23	52	11	36		6
	♑	90	0	75	45	62	4	49	16						

Degreess

Hours { Beforenoon / Afternoon }		XII.	XI. I.	X. II.	IX. III.	VIII. IV.	VII. V.	VI.
		☉ Azi.	☉ Azi.	☉ Azi.	☉ Azi.	☉ Azi.	☉ Azi.	☉ Azi.
Degrees of Latitude.		D. M.	D. M.	D. M.	D. M.	D. M.	D. M.	D. M.
51	♋	90 0	61 31	38 37	21 20	7 31	4 N 20	15 18
	♈ ♎	90 0	70 57	53 25	37 50	24 9	11 45	
	♑	90 0	75 49	62 10	49 40			
52	♋	90 0	62 20	39 41	22 16	8 19	0 N 43	14 59
	♈ ♎	90 0	71 13	53 46	38 14	24 28	11 55	
	♑	90 0	75 53	62 15	49 24			
53	♋	90 0	63 5	40 42	23 12	9 3	3 N 18	14 40
	♈ ♎	90 0	71 27	54 8	38 37	24 45	12 5	
	♑	90 0	75 56	65 19	49 27			
54	♋	90 0	63 48	41 40	24 6	9 47	2 N 49	14 20
	♈ ♎	90 0	71 40	54 29	38 58	25 2	12 14	
	♑	90 0	75 59	62 23	49 30			
55	♋	90 0	64 28	42 36	25 0	10 29	2 N 13	14 0
	♈ ♎	90 0	71 53	54 50	39 19	25 19	12 23	
	♑	90 0	76 2	62 28	49 31			
56	♋	90 0	65 7	43 32	25 55	11 13	1 N 29	13 38
	♈ ♎	90 0	72 5	55 9	39 40	25 35	12 32	
	♑	90 0	76 4	62 30	49 32			
57	♋	90 0	65 43	44 25	26 45	11 55	1 N 8	13 17
	♈ ♎	90 0	72 17	55 27	39 59	25 50	12 40	
	♑	90 0	76 6	62 33	49 33			
58	♋	90 0	66 17	45 15	27 36	12 38	0 N 29	12 58
	♈ ♎	90 0	72 28	55 45	40 18	26 5	12 48	
	♑	90 0	76 9	62 36	49 34			
59	♋	90 0	66 49	46 3	28 25	13 18	0 N 29	12 35
	♈ ♎	90 0	72 38	56 2	40 36	26 20	12 56	
	♑	90 0	76 10	62 38				
60	♋	90 0	67 26	46 50	29 13	13 59	2 N 29	12 15
	♈ ♎	90 0	72 48	56 18	40 54	26 34	13 4	
	♑	90 0	76 12	62 40				
61	♋	90 0	67 48	47 35	29 58	14 40	1 N 29	11 53
	♈ ♎	90 0	72 58	56 35	41 10	26 47	13 12	
	♑	90 0	76 13	62 41				
62	♋	90 0	68 16	48 17	30 45	15 21	1 N 20	11 31
	♈ ♎	90 0	73 7	56 49	41 27	27 0	13 19	
	♑	90 0	76 14	62 42				
63	♋	90 0	69 13					
	♈ ♎	90 0	72 18					
	♒	90 0	75 9					
64	♋	90 0	69 32					
	♈ ♎	90 0	72 50					
	♑	90 0	74 40					
65	♋	90 0	70 0					
	♈ ♎	90 0	71 3					
	♑	90 0	73 0					
66	♋	90 0						
	♈ ♎	90 0						
	♑	90 0						
66½	♋	90 0						
	♈ ♎	90 0						
	♒	90 0						

A TABLE OF NATURAL Sines, Tangents AND SECANTS,

To a Radius of 1.00000,

And to every Sixth Minute (or Tenth Part of a Degree)

OF THE

QUADRANT.

Fitted for the more eaſie Inſcription of the Parallels of the Sun's Courſe, and other FURNITURE

INTO

SUN-DIALS.

D.	*M.*	*Sine*	*Tang.*	*Secant*
0	0	00000	00000	1.00000
	6	174	174	1.00000
	12	349	349	1.00000
	18	523	523	1.00001
	24	698	698	1.00002
	30	872	872	1.00003
	36	1074	1074	1.00005
	42	1221	1221	1.00007
	48	1396	1396	1.00009
	54	1570	1570	1.00012
1	0	1745	1745	1.00015
	6	1919	1920	1.00018
	12	2094	2094	1.00021
	18	2268	2269	1.00025
	24	2443	2443	1.00029
	30	2617	2618	1.00034
	36	2792	2793	1.00039
	42	2966	2967	1.00044
	48	3141	3142	1.00049
	54	3315	3317	1.00055
2	0	3489	3492	1.00060
	6	3664	3666	1.00067
	12	3838	3841	1.00073
	18	4013	4016	1.00080
	24	4187	4191	1.00087
	30	4361	4366	1.00095
	36	4536	4540	1.00103
	42	4710	4715	1.00111
	48	4884	4890	1.00119
	54	5059	5065	1.00128
3	0	5233	5240	1.00137
	6	5407	5415	1.00146
	12	5582	5590	1.00156
	18	5756	5765	1.00166
	24	5930	5941	1.00176
	30	6104	6116	1.00186
	36	6279	6291	1.00197
	42	6453	6466	1.00208
	48	6627	6641	1.00220
	54	6801	6817	1.00232
4	0	6975	6992	1.00244

90	0	1.00000	Infinite.	Infinite
	54	99999	572.95721	572.95808
	48	99999	286.47773	286.47947
	42	99998	190.98418	190.98680
	36	99997	143.23712	143.24061
	30	99996	114.58865	114.59301
	24	99994	95.48947	95.49471
	18	99992	81.84704	81.85314
	12	99990	71.61507	71.62205
	6	99987	63.65674	63.66459
89	0	99984	57.28996	57.29868
	54	99981	52.08067	52.09027
	48	99978	47.73959	47.74997
	42	99974	44.06611	44.07745
	36	99979	40.91741	40.02962
	30	99965	38.18845	38.20155
	24	99961	35.80055	35.81451
	18	99955	33.69350	33.70834
	12	99950	31.82051	31.83622
	6	99945	30.14461	30.16120
88	0	99939	28.63625	28.65370
	54	99932	27.27148	27.28981
	48	99926	26.03073	26.04993
	42	99919	24.89782	24.91790
	36	99912	23.85927	23.88022
	30	99904	22.90376	22.92558
	24	99897	22.02171	22.04440
	18	99888	21.20494	21.22851
	12	99880	20.44648	20.47092
	6	99871	19.74029	19.76560
87	0	99862	19.08113	19.10732
	54	99853	18.46447	18.49153
	48	99844	17.88631	17.91424
	42	99834	17.34315	17.37196
	36	99823	16.83191	16.86159
	30	99813	16.34985	16.38040
	24	99802	15.89454	15.92597
	18	99791	15.46381	15.49611
	12	99780	15.05572	15.08889
	6	99768	14.66852	14.70257
86	0	99756	14.30066	14.33558
D.	*M.*	*Sine*	*Tangent*	*Secant.*

D.	M.	Sine	Tang.	Secant.					
4	0	6975	6992	1.00244	86	0	99756	1.430066	1.433558
	6	7149	7168	1.00256		54	99744	1.395071	1.398651
	12	7323	7343	1.00269		48	99731	1.361740	1.365407
	18	7497	7519	1.00282		42	99718	1.329957	1.333711
	24	7671	7694	1.00295		36	99705	1.299615	1.303457
	30	7845	7870	1.00309		30	99691	1.260620	1.274549
	36	8019	8045	1.00323		24	99677	1.242883	1.246899
	42	8193	8221	1.00337		18	99663	1.216323	1.220427
	48	8367	8397	1.00351		12	99649	1.190868	1.195059
	54	8541	8573	1.00366		6	99634	1.166449	1.170728
5	0	8715	8748	1.00381	85	0	99619	1.143005	1.147371
	6	8889	8924	1.00397		54	99604	1.120478	1.124931
	12	9063	9100	1.00413		48	99588	1.098815	1.103355
	18	9237	9276	1.00429		42	99572	1.077967	1.082595
	24	9410	9452	1.00445		36	99556	1.057889	1.062605
	30	9584	9628	1.00462		30	99539	1.038539	1.043343
	36	9758	9805	1.00479		24	99522	1.019878	1.024769
	42	9931	9981	1.00496		18	99505	1.001870	1.006849
	48	10105	10157	1.00514		12	99488	984481	989547
	54	10279	10334	1.00532		6	99470	967680	972833
6	0	10452	10510	1.00550	84	0	99452	951436	956677
	6	10626	10686	1.00569		54	99433	935723	941051
	12	10799	10863	1.00588		48	99415	920515	925931
	18	10973	11040	1.00607		42	99396	905788	911292
	24	11146	11216	1.00627		36	99376	891520	897110
	30	11320	11393	1.00646		30	99357	877688	883367
	36	11493	11570	1.00667		24	99337	864274	870040
	42	11667	11747	1.00687		18	99317	851259	857112
	48	11840	11924	1.00708		12	99296	838625	844566
	54	12013	12101	1.00729		6	99275	826355	832384
7	0	12186	12278	1.00750	83	0	99254	814434	820550
	6	12360	12455	1.00772		54	99233	802847	809051
	12	12533	12632	1.00794		48	99211	791581	797872
	18	12706	12810	1.00817		42	99189	780622	787001
	24	12879	12987	1.00839		36	99167	769957	776424
	30	13052	13165	1.00862		30	99144	759575	766129
	36	13225	13342	1.00886		24	99121	749465	756107
	42	13398	13520	1.00909		18	99098	739615	746345
	48	13571	13698	1.00933		12	99074	730017	736835
	54	13744	13876	1.00958		6	99050	720661	727566
8	0	13917	14054	1.00982	82	0	99026	711536	718529
					D.	M.	Sine	Tangent	Secant.

D.	M.	Sine	Tang.	Secant
8	0	13917	14054	1.00982
	6	14090	14232	1.01007
	12	14263	14410	1.01032
	18	14435	14588	1.01058
	24	14608	14766	1.01084
	30	14780	14945	1.01110
	36	14953	15123	1.01137
	42	15126	15302	1.01164
	48	15298	15480	1.01191
	54	15471	15659	1.01218
9	0	15643	15838	1.01246
	6	15815	16017	1.01274
	12	15988	16196	1.01303
	18	16160	16375	1.01331
	24	16332	16554	1.01361
	30	16504	16734	1.01390
	36	16676	16913	1.01420
	42	16848	17093	1.01450
	48	17020	17273	1.01480
	54	17192	17452	1.01511
10	0	17364	17632	1.01542
	6	17536	17812	1.01574
	12	17708	17992	1.01605
	18	17880	18173	1.01637
	24	18051	18353	1.01670
	30	18222	18533	1.01703
	36	18395	18714	1.01736
	42	18516	18895	1.01769
	48	18738	19076	1.01803
	54	18909	19256	1.01837
11	0	19080	19438	1.01871
	6	19252	19619	1.01906
	12	19423	19800	1.01941
	18	19594	19981	1.01976
	24	19765	20163	1.01012
	30	19936	20345	1.02048
	36	20107	20527	1.02085
	42	20278	20709	1.02121
	48	20449	20891	1.02158
	54	20620	21073	1.02196
12	0	20791	21255	1.02234

82	0	99026	7.11536	7.18529
	54	99002	7.02636	7.09717
	48	98977	6.93951	7.01120
	42	98952	6.85475	6.92730
	36	98929	6.77198	6.84542
	30	98901	6.69115	6.76546
	24	98875	6.61219	6.68738
	18	98849	6.53502	6.61109
	12	98822	6.45960	6.53655
	6	98795	6.38586	6.46369
81	0	98768	6.31375	6.39245
	54	98741	6.24320	6.32278
	48	98713	6.17418	6.25464
	42	98685	6.10663	6.18797
	36	98657	6.04051	6.12272
	30	98628	5.97576	6.05887
	24	98599	5.91235	5.99632
	18	98570	5.85024	5.93509
	12	98540	5.78938	5.87511
	6	98510	5.72974	5.81635
80	0	98480	5.67128	5.75877
	54	98450	5.61396	5.70233
	48	98419	5.55776	5.64701
	42	98388	5.50264	5.59277
	36	98357	5.44857	5.53957
	30	98325	5.39551	5.48740
	24	98293	5.34345	5.43621
	18	98261	5.19235	5.38599
	12	98228	5.24218	5.33671
	6	98195	5.19292	5.28833
79	0	98162	5.14455	5.24084
	54	98129	5.09704	5.19421
	48	98095	5.05036	5.14841
	42	98061	5.00451	5.10344
	36	98027	4.95944	5.05926
	30	97992	4.91515	5.01585
	24	97957	4.87162	4.97319
	18	97922	4.82881	4.93127
	12	97886	4.78673	4.89207
	6	97850	4.74534	4.84956
78	0	97814	4.70463	4.80973
D.	M.	Sine	Tangent	Secant.

D.	M.	Sine	Tang.	Secant.
12	0	20791	21255	1.02234
	6	20961	21438	1.02272
	12	21132	21620	1.02310
	18	21303	21803	1.02349
	24	21473	21986	1.02388
	30	21643	22169	1.02427
	36	21814	22352	1.02467
	42	21984	22535	1.02507
	48	22154	22719	1.02548
	54	22325	22903	1.02589
13	0	22495	23086	1.02630
	6	22665	23270	1.02671
	12	22835	23454	1.02713
	18	23004	23639	1.02756
	24	23174	23823	1.02798
	30	23344	24007	1.02841
	36	23514	24192	1.02884
	42	23683	24377	1.02928
	48	23853	24562	1.02972
	54	24022	24747	1.03016
14	0	24192	24932	1.03061
	6	24361	25118	1.03106
	12	24530	25303	1.03151
	18	24699	25489	1.03197
	24	24868	25675	1.03243
	30	25038	25861	1.03290
	36	25206	26048	1.03336
	42	25375	26234	1.03383
	48	25544	26421	1.03431
	54	25713	26607	1.03471
15	0	25881	26794	1.03527
	6	26050	26982	1.03576
	12	26218	27169	1.03625
	18	26387	27356	1.03674
	24	26555	27544	1.03724
	30	26723	27732	1.03774
	36	26891	27920	1.03824
	42	27060	28108	1.03875
	48	27228	28297	1.03926
	54	27395	28485	1.03978
16	0	27563	28674	1.04229

78	0	97814	4.70463	4.80973
	54	97778	4.66458	4.77056
	48	97741	4.62518	4.73205
	42	97704	4.58641	4.69416
	36	97667	4.54826	4.65689
	30	97629	4.51070	4.62022
	24	97591	4.47374	4.58414
	18	97553	4.43734	4.54863
	12	97514	4.40151	4.51368
	6	97476	4.36622	4.47928
77	0	97437	4.33147	4.44541
	54	97397	4.29724	4.41206
	48	97357	4.26352	4.37922
	42	97317	4.23029	4.34688
	36	97277	4.19756	4.31503
	30	97236	4.16529	4.28365
	24	97196	4.13350	4.25274
	18	97154	4.10216	4.22229
	12	97113	4.07127	4.19228
	6	97071	4.04081	4.16271
76	0	97029	4.01078	4.13356
	54	96987	3.98116	4.10483
	48	96944	3.95196	4.07651
	42	96901	3.92315	4.04859
	36	96858	3.89474	4.02107
	30	96814	3.86671	3.99392
	24	96770	3.83905	3.96716
	18	96726	3.81177	3.94076
	12	96682	3.78484	3.91472
	6	96637	3.75827	3.88904
75	0	96592	3.73205	3.86370
	54	96547	3.70616	3.83870
	48	96501	3.68061	3.81403
	42	96455	3.65538	3.78970
	36	96409	3.63047	3.76568
	30	96363	3.60588	3.74197
	24	96316	3.58159	3.71858
	18	96269	3.55761	3.69548
	12	96221	3.53392	3.67268
	6	96174	3.51052	3.65017
74	0	96126	3.48741	3.62795
D.	M.	Sine	Tangent	Secant.

D.	M.	Sine	Tang.	Secant
16	0	27563	28674	1.04029
	6	27731	28863	1.04082
	12	27899	29052	1.04134
	18	28066	29242	1.04187
	24	28234	29431	1.04241
	30	28401	29621	1.04294
	36	28568	29811	1.04349
	42	28736	30001	1.04403
	48	28903	30191	1.04458
	54	29070	30382	1.04513
17	0	29237	30573	1.04569
	6	29404	30764	1.04625
	12	29570	30955	1.04681
	18	29737	31146	1.04738
	24	29904	31338	1.04795
	30	30070	31529	1.04852
	36	30236	31721	1.04910
	42	30403	31914	1.04969
	48	30569	32106	1.05027
	54	30735	32299	1.05086
18	0	30901	32491	1.05146
	6	31067	32685	1.05206
	12	31233	32878	1.05266
	18	31399	33071	1.05326
	24	31564	33265	1.05387
	30	31730	33459	1.05449
	36	31895	33653	1.05511
	42	32061	33848	1.05573
	48	32226	34042	1.05635
	54	32391	34237	1.05698
19	0	32556	34432	1.05762
	6	32721	34628	1.05825
	12	32886	34823	1.05889
	18	33051	35019	1.05954
	24	33216	35215	1.06019
	30	33380	35411	1.06084
	36	33545	35608	1.06150
	42	33709	35805	1.06216
	48	33873	36002	1.06283
	54	34037	36199	1.06350
20	0	34202	36397	1.06417

74	0	96126	3.48741	3.62795
	54	96077	3.46458	3.60601
	48	96029	3.44202	3.58434
	42	95980	3.41973	3.56294
	36	95931	3.39770	3.54181
	30	95881	3.37594	3.52093
	24	95832	3.35443	3.50031
	18	95782	3.33317	3.47994
	12	95731	3.31215	3.45982
	6	95681	3.39138	3.43994
73	0	95630	3.27085	3.42030
	54	95579	3.25055	3.40089
	48	95527	3.23047	3.38171
	42	95476	3.21063	3.36275
	36	95424	3.19100	3.34402
	30	95371	3.17159	3.32550
	24	95319	3.15239	3.30720
	18	95266	3.13341	3.28911
	12	95212	3.11463	3.27123
	6	95159	3.09605	3.25354
72	0	95105	3.07768	3.23606
	54	95051	3.05950	3.21878
	48	94997	3.04151	3.20169
	42	94942	3.02372	3.18478
	36	94887	3.00611	3.16807
	30	94832	2.98868	3.15154
	24	94776	2.97143	3.13519
	18	94721	2.95437	3.11902
	12	94664	2.93747	3.10302
	6	94608	2.92076	3.08720
71	0	94551	2.90421	3.07155
	54	94494	2.88782	3.05606
	48	94437	2.87160	3.04074
	42	94380	2.85555	3.02558
	36	94322	2.83965	3.01058
	30	94264	2.82391	2.99574
	24	94205	2.80832	2.98105
	18	94147	2.79289	2.96652
	12	94088	2.77760	2.95213
	6	94028	2.76246	2.93789
70	0	93969	2.74747	2.92380
D.	M.	Sine	Tangent	Secant.

D.	M.	Sine	Tang.	Secant.
20	0	34202	36397	1.06417
	6	34365	36594	1.06485
	12	34529	36792	1.06553
	18	34693	36991	1.06622
	24	34857	37189	1.06691
	30	35020	37388	1.06760
	36	35184	37587	1.06830
	42	35347	37786	1.06901
	48	35510	37986	1.06971
	54	35673	38206	1.07042
21	0	35836	38386	1.07114
	6	35999	38586	1.07186
	12	36162	38787	1.07258
	18	36325	38988	1.07391
	24	36487	39189	1.07404
	30	36650	39391	1.07478
	36	36812	39592	1.07552
	42	36974	39794	1.07627
	48	37136	39997	1.07702
	54	37298	40199	1.07777
22	0	37460	40402	1.07853
	6	37622	40605	1.07929
	12	37784	40809	1.08006
	18	37945	41012	1.08083
	24	38107	41217	1.08161
	30	38268	41421	1.08239
	36	38429	41625	1.08317
	42	38590	41830	1.08396
	48	38751	42036	1.08475
	54	38912	42241	1.08555
23	0	39073	42447	1.08636
	6	39233	42643	1.08716
	12	39394	42860	1.08797
	18	39554	43066	1.08879
	24	39714	43273	1.08961
	30	39874	43481	1.09044
	36	40034	43688	1.09127
	42	40194	43896	1.09210
	48	40354	44105	1.09294
	54	40514	44313	1.09378
24	0	40673	44522	1.09463

D.	M.	Sine	Tangent	Secant.
70	0	93969	2.74747	2.92380
	54	93909	2.73262	2.90985
	48	93849	2.71792	2.89604
	42	93788	2.70335	2.88237
	36	93728	2.68891	2.86884
	30	93667	2.67462	2.85545
	24	93605	2.66045	2.84218
	18	93544	2.64642	2.82905
	12	93482	2.63251	2.81605
	6	93420	2.61874	2.80317
69	0	93358	2.60508	2.79042
	54	93295	2.59156	2.77780
	48	93232	2.57815	2.76529
	42	93169	2.56486	2.75291
	36	93105	2.55169	2.74065
	30	93041	2.53864	2.72850
	24	92977	2.52571	2.71647
	18	92913	2.51288	2.70455
	12	92848	2.50017	2.69274
	6	92783	2.48757	2.68105
68	0	92718	2.47508	2.66946
	54	92652	2.46272	2.65798
	48	92587	2.45042	2.64661
	42	92520	2.43825	2.63535
	36	92454	2.42618	2.62418
	30	92387	2.41421	2.61312
	24	92321	2.40234	2.60216
	18	92253	2.39057	2.59130
	12	92186	2.37890	2.58054
	6	92118	2.36733	2.56987
67	0	92050	2.35585	2.55930
	54	91982	2.34446	2.54882
	48	91913	2.33317	2.53844
	42	91844	2.32197	2.52815
	36	91775	2.31086	2.51795
	30	91706	2.29984	2.50784
	24	91636	2.28890	2.49782
	18	91566	2.27806	2.48788
	12	91495	2.26730	2.47803
	6	91425	2.25662	2.46827
66	0	91354	2.24603	2.45859

D.	M.	Sine	Tang.	Secant.
24	0	40673	44522	1.09463
	6	40833	44732	1.09548
	12	40992	44941	1.09634
	18	41151	45151	1.09720
	24	41310	45362	1.09807
	30	41469	45572	1.09894
	36	41628	45783	1.09982
	42	41786	45994	1.10070
	48	41945	46206	1.10159
	54	42103	46418	1.10248
25	0	42261	46630	1.10337
	6	42419	46843	1.10427
	12	42577	47056	1.10518
	18	42735	47269	1.10609
	24	42893	47483	1.10700
	30	43051	47697	1.10792
	36	43208	47911	1.10885
	42	43365	48126	1.10978
	48	43523	48341	1.11071
	54	43680	48557	1.11165
26	0	43837	48773	1.11260
	6	43993	48989	1.11355
	12	44150	49206	1.11450
	18	44307	49423	1.11546
	24	44463	49640	1.11643
	30	44619	49858	1.11740
	36	44775	50076	1.11837
	42	44931	50294	1.11935
	48	45087	50513	1.12034
	54	45243	50732	1.12133
27	0	45399	50952	1.12232
	6	45554	51172	1.12332
	12	45709	51393	1.12433
	18	45864	51613	1.12534
	24	46019	51835	1.12636
	30	46174	52056	1.12738
	36	46329	52278	1.12840
	42	46484	52501	1.12944
	48	46638	52724	1.13047
	54	46792	52947	1.13152
28	0	46947	53170	1.13257

D.	M.	Sine	Tangent	Secant.
66	0	91354	2.24603	2.45859
	54	91285	2.23552	2.44897
	48	91212	2.22510	2.33948
	42	91140	2.21475	2.43004
	36	91068	2.20448	2.42069
	30	90996	2.19429	2.41142
	24	98923	2.18418	2.40222
	18	90850	2.17415	2.39310
	12	90777	2.16419	2.38406
	6	90704	2.15431	2.37509
65	0	90630	2.14450	2.36620
	54	90556	2.13477	2.35738
	48	90482	2.12510	2.34863
	42	90408	2.11551	2.33995
	36	90333	2.10599	2.33135
	30	90258	2.09654	2.32282
	24	90183	2.08716	2.31435
	18	90107	2.07784	2.30595
	12	90031	2.06859	2.29762
	6	89955	2.05941	2.28936
64	0	89879	2.05030	2.28117
	54	89802	2.04125	2.27304
	48	89725	2.03126	2.26497
	42	89648	2.02334	2.25697
	36	89571	2.01448	2.24903
	30	89493	2.00568	2.24115
	24	89415	1.99695	2.23334
	18	89337	1.98827	2.22559
	12	89258	1.97966	2.21789
	6	89179	1.97110	2.21026
63	0	89100	1.96261	2.20268
	54	89021	1.95417	2.19517
	48	88941	1.94578	2.18771
	42	88861	1.93746	2.18031
	36	88781	1.92919	2.17296
	30	88701	1.92098	2.16568
	24	88620	1.91282	2.15844
	18	88539	1.90471	2.15126
	12	88458	1.89666	2.14414
	6	88376	1.88867	2.13707
62	0	88294	1.88072	2.13005
D.	M.	Sine	Tangent	Secant.

D.	M.	Sine	Tang.	Secant.
28	0	46947	53170	1.13257
	6	47101	53395	1.13362
	12	47255	53619	1.13468
	18	47408	53844	1.13574
	24	47562	54069	1.13681
	30	47715	54295	1.13789
	36	47869	54521	1.13897
	42	48022	54748	1.14006
	48	48175	54975	1.14115
	54	48328	55202	1.14225
29	0	48480	55430	1.14335
	6	48633	55659	1.14446
	12	48785	55888	1.14557
	18	48938	56117	1.14669
	24	49090	56347	1.14782
	30	49242	56577	1.14895
	36	49394	56807	1.15009
	42	49545	57038	1.15123
	48	49697	57270	1.15238
	54	49848	57502	1.15353
30	0	50000	57735	1.15470
	6	50151	57967	1.15586
	12	50301	58201	1.15703
	18	50452	58435	1.15821
	24	50603	58669	1.15940
	30	50753	58904	1.16059
	36	50904	59139	1.16178
	42	51054	59375	1.16299
	48	51204	59611	1.16419
	54	51354	59848	1.16541
31	0	51503	60086	1.16663
	6	51653	60323	1.16785
	12	51802	60562	1.16909
	18	51951	60800	1.17033
	24	52100	61040	1.17157
	30	52249	61280	1.17282
	36	52398	61520	1.17428
	42	52547	61761	1.17534
	48	52695	62002	1.17661
	54	52843	62244	1.17789
32	0	52991	62486	1.17917

62	0	88294	1.88072	2.13005
	54	88212	1.87283	2.12308
	48	88130	1.86499	2.11617
	42	88047	1.85720	2.10931
	36	87964	1.84946	2.10250
	30	87881	1.84177	2.09573
	24	87798	1.83412	2.08902
	18	87714	1.82653	2.08236
	12	87630	1.81899	2.07574
	6	87546	1.81149	2.06918
61	0	87461	1.80404	2.06266
	54	87377	1.79664	2.05619
	48	87292	1.78928	2.04976
	42	87206	1.78197	2.04339
	36	87121	1.77471	2.03705
	30	87035	1.76749	2.03077
	24	86949	1.76031	2.02452
	18	86863	1.75318	2.01833
	12	86776	1.74609	2.01217
	6	86689	1.73905	2.00606
60	0	86602	1.73205	2.00000
	54	86515	1.72509	1.99397
	48	86427	1.71817	1.98799
	42	86339	1.71129	1.98205
	36	86251	1.70445	1.97615
	30	86162	1.69766	1.97029
	24	86074	1.69090	1.96447
	18	85985	1.68419	1.95869
	12	85895	1.67751	1.95296
	6	85806	1.67087	1.94726
59	0	85716	1.66427	1.94160
	54	85626	1.65771	1.93598
	48	85536	1.65119	1.93040
	42	85445	1.64471	1.92485
	36	85355	1.63826	1.91935
	30	85264	1.63185	1.91388
	24	85172	1.62547	1.90844
	18	85081	1.61913	1.90305
	12	84989	1.61283	1.89769
	6	84897	1.60656	1.89236
58	0	84804	1.60033	1.88707
D.	M.	Sine	Tangent	Secant.

D.	M.	Sine	Tang.	Secant
32	0	52991	62486	1.17917
	6	53139	62729	1.18046
	12	53287	62973	1.18176
	18	53435	63217	1.18306
	24	53582	63461	1.18437
	30	53729	63707	1.18568
	36	53877	63952	1.18701
	42	54024	64198	1.18833
	48	54170	64445	1.18967
	54	54317	64692	1.19101
33	0	54463	64940	1.19236
	6	54610	65189	1.19371
	12	54756	65438	1.19507
	18	54902	65687	1.19644
	24	55058	65937	1.19782
	30	55193	66188	1.19920
	36	55339	66439	1.20059
	42	55484	66691	1.20198
	48	55629	66944	1.20339
	54	55777	67197	1.20480
34	0	55919	67450	1.20621
	6	56063	67705	1.20764
	12	56208	67959	1.20907
	18	56352	68215	1.21050
	24	56496	68471	1.21195
	30	56640	68728	1.21340
	36	56784	68985	1.21486
	42	56927	69243	1.21633
	48	57071	69501	1.21780
	54	57214	69760	1.21928
35	0	57357	70020	1.22077
	6	57500	70281	1.22227
	12	57643	70542	1.22377
	18	57785	70803	1.22528
	24	57928	71056	1.22680
	30	58070	71329	1.22832
	36	58212	71592	1.22985
	42	58354	71857	1.23140
	48	58495	72122	1.23294
	54	58637	72387	1.23450
36	0	58778	72654	1.23606

58	0	84804	1.60033	1.88707
	54	84712	1.59413	1.88182
	48	84619	1.58797	1.87660
	42	84526	1.58184	1.87142
	36	84432	1.57574	1.86627
	30	84339	1.56968	1.86115
	24	84245	1.56365	1.85607
	18	84151	1.55766	1.85102
	12	84056	1.55169	1.84601
	6	83961	1.54576	1.84102
57	0	83867	1.53986	1.83607
	54	83771	1.53399	1.83115
	48	83676	1.52816	1.82627
	42	83580	1.52235	1.82141
	36	83484	1.51657	1.81659
	30	83388	1.51083	1.81180
	24	83292	1.50512	1.80703
	18	83195	1.49943	1.80230
	12	83098	1.49378	1.79760
	6	83001	1.48815	1.79293
56	0	82903	1.48256	1.78829
	54	82806	1.47699	1.78367
	48	82708	1.47145	1.77909
	42	82609	1.46594	1.77454
	36	82511	1.46046	1.77001
	30	82412	1.45500	1.76551
	24	82313	1.44958	1.76104
	18	82214	1.44418	1.75660
	12	82114	1.43881	1.75219
	6	82015	1.43346	1.74780
55	0	81915	1.42814	1.74344
	54	81814	1.42285	1.73911
	48	81714	1.41759	1.73480
	42	81613	1.41235	1.73053
	36	81512	1.40713	1.72627
	30	81411	1.40194	1.72205
	24	81310	1.39678	1.71785
	18	81208	1.39164	1.71367
	12	81106	1.38653	1.70952
	6	81004	1.38144	1.70540
54	0	80901	1.37638	1.70130
D.	M.	Sine	Tangent	Secant.

D.	M.	Sine	Tang.	Secant.	D.	M.	Sine	Tangent	Secant.
36	0	58778	72654	1.23606	54	0	80901	1.37638	1.70130
	6	58919	72921	1.23763		54	80798	1.3713[illegible]	1.69722
	12	59060	73188	1.23921		48	80696	1.36632	1.69317
	18	59201	73457	1.24080		42	80592	1.36133	1.68915
	24	59341	73726	1.24239		36	80489	1.35636	1.68515
	30	59482	73996	1.24400		30	80385	1.35142	1.68117
	36	59622	74266	1.24561		24	80281	1.34650	1.67721
	42	59762	74537	1.24723		18	80177	1.34160	1.67328
	48	59902	74809	1.24885		12	80073	1.33672	1.66938
	54	60042	75082	1.25049		6	79968	1.33187	1.66552
37	0	60181	75355	1.25213	53	0	79863	1.32704	1.66164
	6	60320	75629	1.25378		54	79758	1.32223	1.65780
	12	60459	75904	1.25544		48	79652	1.31745	1.65398
	18	60598	76179	1.25711		42	79547	1.31268	1.65019
	24	60737	76455	1.25878		36	79441	1.30794	1.64642
	30	60876	76732	1.26047		30	79335	1.30322	1.64267
	36	61014	77010	1.26216		24	79228	1.29852	1.63895
	42	61152	77288	1.26386		18	79122	1.29384	1.63525
	48	61290	77567	1.26557		12	79015	1.28919	1.63156
	54	61428	77847	1.26729		6	78908	1.28455	1.62790
38	0	61566	78128	1.26901	52	0	78801	1.27994	1.62426
	6	61703	78410	1.27075		54	78693	1.27534	1.62065
	12	61840	78692	1.27249		48	78585	1.27077	1.61705
	18	61977	78975	1.27424		42	78477	1.26621	1.61347
	24	62114	79259	1.27600		36	78369	1.26168	1.60992
	30	62251	79543	1.27777		30	78260	1.25717	1.60638
	36	62387	79828	1.27955		24	78152	1.25267	1.60287
	42	62524	80115	1.28134		18	78043	1.24820	1.59937
	48	62660	80402	1.28314		12	77933	1.24374	1.59590
	54	62756	80689	1.28494		6	77824	1.23931	1.59245
39	0	62932	80978	1.28675	51	0	77714	1.23489	1.58901
	6	63067	81267	1.28858		54	77604	1.23049	1.58560
	12	63202	81558	1.29041		48	77494	1.22612	1.58220
	18	63338	81849	1.29225		42	77384	1.22176	1.57882
	24	63473	82140	1.29410		36	77273	1.21741	1.57547
	30	63607	82433	1.29596		30	77162	1.21309	1.57213
	36	63742	82727	1.29783		24	77051	1.20879	1.50881
	42	63876	83021	1.29971		18	76939	1.20450	1.56551
	48	64010	83316	1.30160		12	76828	1.20023	1.56223
	54	64144	83612	1.30350		6	76716	1.19598	1.55896
40	0	64278	83909	1.30540	50	0	76604	1.19175	1.55572
					D.	M.	Sine	Tangent	Secant.

D.	M.	Sine	Tang.	Secant
40	0	64278	83909	1.30540
	6	64412	84207	1.30732
	12	64545	84506	1.30925
	18	64678	84806	1.31118
	24	64811	85106	1.31313
	30	64944	85408	1.31508
	36	65077	85710	1.31705
	42	65209	86013	1.31902
	48	65342	86318	1.32101
	54	65474	86622	1.32300
41	0	65605	86928	1.32501
	6	65737	87235	1.32702
	12	65868	87543	1.32905
	18	66000	87852	1.33108
	24	66131	88161	1.33313
	30	66262	88472	1.33519
	36	66392	88784	1.33725
	42	66523	89096	1.33933
	48	66653	89410	1.34142
	54	66783	89724	1.34352
42	0	66913	90040	1.34563
	6	67042	90356	1.34775
	12	67172	90674	1.34988
	18	67301	90993	1.35202
	24	67430	91312	1.35417
	30	67559	91633	1.35634
	36	67687	91954	1.35851
	42	67835	92277	1.36070
	48	67944	92601	1.36289
	54	68072	92925	1.36510
43	0	68199	93251	1.36732
	6	68327	93578	1.36955
	12	68454	93906	1.37180
	18	68581	94235	1.37405
	24	68708	94565	1.37632
	30	68835	94896	1.37859
	36	68961	95228	1.38088
	42	69088	95562	1.38318
	48	69214	95896	1.38550
	54	69340	96232	1.38782
44	0	69465	26568	1.39016

50	0	76604	1.19175	1.55572
	54	76492	1.18753	1.55249
	48	76379	1.18334	1.54928
	42	76266	1.17915	1.54609
	36	76153	1.17499	1.54292
	30	76040	1.17084	1.53976
	24	75927	1.16672	1.53663
	18	75813	1.16260	1.53351
	12	75699	1.15851	1.53040
	6	75585	1.15443	1.52732
49	0	75470	1.15036	1.52425
	54	75356	1.14632	1.52120
	48	75241	1.14229	1.51816
	42	75126	1.13827	1.51514
	36	75011	1.13427	1.51214
	30	74895	1.13029	1.50916
	24	74779	1.12632	1.50619
	18	74663	1.12237	1.50323
	12	74547	1.11843	1.50030
	6	74431	1.11451	1.49738
48	0	74314	1.11061	1.49447
	54	74197	1.10672	1.49158
	48	74080	1.10284	1.48871
	42	73963	1.09898	1.48585
	36	73845	1.09513	1.48301
	30	73727	1.09130	1.48018
	24	73609	1.08749	1.47737
	18	73491	1.08368	1.47457
	12	73372	1.07990	1.47179
	6	73254	1.07612	1.46903
47	0	73135	1.07236	1.46627
	54	73016	1.06862	1.46354
	48	72896	1.06489	1.46081
	42	72777	1.06117	1.45811
	36	72657	1.05747	1.45541
	30	72537	1.05378	1.45273
	24	72417	1.05010	1.45007
	18	72296	1.04644	1.44742
	12	72176	1.04279	1.44478
	6	72055	1.03915	1.44216
46	0	71933	1.03553	1.43955
D.	M.	Sine	Tangent	Secant.

D.	M.	Sine	Tang.	Secant.
44	0	69465	96568	1.39016
	6	69591	96906	1.39251
	12	69716	97245	1.39487
	18	69841	97585	1.39724
	24	69966	97927	1.39963
	30	70090	98269	1.40203
	36	70215	98613	1.40444
	42	70339	98958	1.40686
	48	70463	99304	1.40930
	54	70587	99651	1.41175
45	0	70710	1.00000	1.41421

46	0	71933	1.03553	1.43955
	54	71812	1.03191	1.43696
	48	71691	1.02832	1.43438
	42	71569	1.02473	1.43181
	36	71447	1.02116	1.42925
	30	71325	1.01760	1.42671
	24	71202	1.01406	1.42419
	18	71079	1.01052	1.42167
	12	70957	1.00700	1.41917
	6	70831	1.00349	1.41668
45	0	70710	1.00000	1.41421
D.	M.	Sine	Tangent	Secant.

The End of the Sixth TRACTATE.

A Succinct and Demonstrable Way of Describing HOUR-LINES Upon all Sorts of PLAINS.

And also,

For the Inscription of other Sciaterical Furniture into SUN-DIALS.

Translated from a *Latin* Manuscript written, *Anno* 1640. By *Samuel Foster*, sometimes Professor of Astronomy in *Gresham* Colledge, *LONDON.*

The Seventh TRACTATE.

IN all the six Schemes —— NESW represents the Horizon. —— NPS the Meridian —— TRL the Plain —— P the Pole of the Word —— Z the Pole of the Horizon —— O the Pole of the Plain —— DN or DS, the Declination of the Plain, which two Arks are Complements of each other; and unto which, the Angles PZO or OZS are Equal.

The Horizontal Line of the Plain is TZL —— The Vertical Line VZ —— The Inclination of the Plain to the Horizon, is the Arch VC, to which OZ is equal.

That the Axis and Hour-lines may be duly seated, we must of necessity solve the Spherical Triangle PZO, in which there are given, (1.) PZ, the Complement of the Latitude, (2.) ZO, the Inclination of the Plain to the Horizon, (3.) The Angle PZO, the Declination of the Plain from the North.

Therefore, it is evident, by the Fourth Axiom,

First, The Base PO, whose excess above a Quadrant in the III. Scheme, is the Complement to a Quadrant in the other Schemes; And therefore PR is the Elevation of the Pole above the Plain.

note, the figures this Tractate is page 49. of the first

Secondly, By the Third Axiom.
As the Sine of the Arch, before found, OP
Is to the Sine of the Declination PZO, or OZS,
So is the Sine of the Inclination of the Plain to the Horizon OZ,
To the Sine of OPZ. The difference of Longitude between the Meridian of the Plain, and the Meridian of the Place.

Thirdly, By the Third Axiom.
As the Sine of the Arch OP,
Is to the Sine of the Declination ZO, or OZS;
So is the Sine of PZ, the Complement of the Latitude of the Place,
To the Sine of the Angle POZ, or RV.
Which is the diſtance of the Subſtile and Meridian.

¶ *To find the Subſtile and to place the Axis upon it.*

The Subſtile is diſtant from the Vertical Line of the Plain, by the quantity of the Arch RV, and towards the ſame Coaſt, as appears by the Scheme. The Stile ſtanding perpendicular upon this repreſents the Axis of the World; and therefore looks towards the Elevated Pole, making an Angle with the Subſtile equal to the Arch PR.

¶ *To find the Diſtances of the Hour-lines from the Subſtile.*

The Hour-lines are placed from the Subſtile, in the ſame Order which they keep in the Schemes; their Angles being found out by this Proportion.

As Radius
Is to the Sine Elevation of the Pole above the Plain PR.
So are the Tangents of the Angles RP 12, RP 1, RP 2, RP 3, RP 4, RP 5, RP 6, *&c.* —— RP 11, ZP 10, RP 9, RP 8, RP 7, RP 6, *&c.*
To the Tangents of the Arches upon the Plain, R 12, R 1, *&c.* R 11, R 10, *&c.*

From the Meaſures of theſe Arches, let there be Angles deſcribed upon the Plain; and if you draw ſtrait Lines from the Centre through thoſe Points, they will be the Hour-lines: And the Schemes will ſhew the Order of their Numeration.

The true Angles RP 12, RP 1, *&c.* RP 11, RP 10, *&c.* are diſcovered by being compared with the difference of Longitude OPZ, whether it be 1, 2, 3, 4, *&c.* hours from the Meridian, by taking either their Sum or Difference, which is eaſily apprehended from the Schemes.

Moreover, It is to be noted, That the Angle OPZ is Acute, or at the moſt not exceeding a Right Angle. —— But if at any time it fall out to be Obtuſe, the ſame ſhall be the Supplement of the Plain's Difference of Longitude. The ſame is to be underſtood in any Caſe whatſoever, when the Angle RP*m*, is either equal to, or Supplement to the Angles RP 12, RP 1, *&c.*

I have aſſumed theſe Inventions in the laſt place, becauſe they are more commodious for animadverſion.

How

How to know under what Scheme, any Plain falls.

As Radius,
Is to the Co-ſine of the Plain's Declination,
So is the Tangent of the Plain's Inclination to the Horizon,
To a Fourth Tangent:
In North Incliners N *m*,
In South Incliners S *m*;
In both which, if the Fourth Arch N *m* be leſſer than the Elevation of the Pole NP.
The Plain ſhall be like that in Scheme II.
If Greater like that in Scheme III.
If Equal the Plain is Meridianal.

And in theſe,
If the ſaid Fourth Arch S *m* be greater than the Elevation of the Equator SÆ, or Equal to it, the Plain will agree with Scheme IV —— But if leſſer with Scheme V.

Let Erect Plains be repreſented by Scheme I. where, If the Declination be 90 deg. the Plain ſhall be NPZS.

For Direct Incliners beholding the Eaſt or Weſt, the VI Scheme will ſerve. —— But where the Inclination to the Horizon is 90 deg. the Plain ſhall be NZS Meridanal.

Hitherto of the Deſcription of Hours.

CERTAIN

CERTAIN PRECEPTS.
FOR THE
INSCRIPTION
OR OTHER
Sciaterical Furniture
UPON
SUN-DIALS.

PROBL. I.

To find the Distances of the Verticals of their Plains, from the Verticals of the Horizon.

THe Verticals of the Plain is VZ or DC,

The Verticals of the Horizon are ZQ, ZF, ZG and ZH, &c.

The Verticals of the Arch sought of the Distances in Plain are VY, VI, VK, VM, &c.

But because the Declination of the Plain SD or NC, and the Horizontal Distances of the Verticals NQ, NF, NG, NH, &c. from N are known: The Distances also or Sums of the same (according as shall be required) shall be made known: Namely the Arches CQ, CF, CG, CH, &c.

And because ZV is the Complement of the Inclination of the Plain to the Horizon, therefore

As ZC Radius

To Sine of ZV.

So the Tangents of the Arches CQ, CF, CG, CH, &c.

To the Tangents of the sought Arches VY, VI, VK, VM, &c.

In Erect Plains, which pass through the Vertex of the place, those Arches vanish.

PROBL. II.

The Declination of the Parallel from the Equator being given, to find its Distance from the Vertex of the Plain, to any Hour.

LEt the Parallel be A ♋, and the hour ZPA, the Eighth from Midnight or Four before Noon, and let an Arch of a great Circle OA be drawn, then in the Triangle OPA the Sides PA, (by the Declination from the Equator

quator B A) and P O (from the former computation) being known, with the comprehended Angle O P A, made from the Sum or Difference of the Angles OPZ the Difference of Longitude, and ZPA the hour given, the Baſe O A may be found, by the Fourth Axiom: which is the Diſtance of the Point A from O the Vertex of the Plain.

In the ſame manner, the Diſtances to all Parallels and hours are to be ſought.——But to ſeek them beyond 80 deg. will be needleſs.

APPENDIX.

If it be ſought, in what Vertical Circle of the Plain this Diſtance ſhall happen, uſe this following Analogy.

As the Sine of the Side O A
To the Sine of the oppoſite Angle O P A.
So (by the Axiom 3) is the Sine of the Side P A
To the Sine of the oppoſite Angle P O A.
Which is the Latitude, between the Vertical of the Plain O A, and the Subſtilar O P.

PROBL. III.

To find the Diſtance of any Circle Parallel to the Horizon from the Vertex of the Plain, to any Vertical Circle.

LEt the Parallel or Almicanter paſſing through the Point X be the Vertical of the Circle Z F and let the Diſtance of the Point X be ſought, from O the Vertex of the Plain.

Then let the Arch of a great Circle OX be deſcribed, ſo as to make the Triangle OZX, in which from the given Sides OZ (equal to the Inclination VC) and ZX (the Complement of the Diſtance of the Parallel X, from the Horizon F) together with the comprehended Angle OZK, (the Supplement of the Angle C Z F before found) the Baſe O X may be found (by Axiom 4.) which is the Diſtance required.

The ſame is to be found in all other as well Verticals as Parallels. But to ſeek the Diſtances beyond 80 deg. is needleſs.

APPENDIX.

But if it be further required in what Vertical Circle of the Plain, this Diſtance ſhall happen, it may be found in the Third Axiom in this manner:

As the Sine of the Side OX
Is to the Sine of the oppoſite Angle ZOX,
So is the Sine of the Side ZX
To the Sine of the oppoſite Angle ZOX,
Which ſhews how far the Vertical of the Plain, which paſſeth thro' X, is to be diſtant from that Vertical of the Plain OZV.

The Uſe of theſe Problems is for the deſcribing of Vertical Circles parallel to the Equator, and parallel to the Horizon.

In the firſt place the Gnomon is to be aſſigned, according to whoſe ſituation and length all things whatſoever that are to be inſerted in Dials are determined.

Therefore any Point in the Stile being aſſigned for the Apex or point of the Gnomon:

A right line from that point perpendicularly extended to the Plain, ſhall be the length of the Gnomon: And that point of the Plain upon which that right Line falleth, ſhall be taken for the foot of the Gnomon.

To the Gnomon thus conſtituted, are to be fitted both an Horizontal and a Vertical Line upon the Plain, in which alſo the Zenith of the Horizon is to be fixed, all which we ſhall uſe in the deſcription following.

The Horizontal Line may be deſcribed by marking upon the Plain a Point *in equilibrio* with the Apex, and drawing through that point upon the Plain, a Line parallel to the Horizon, both which may be done by an ordinary Inclinatory or Quadrant, or by any other apt or convenient means.

And a right Line drawn through the foot of the Gnomon, perpendicularly to the Horizontal Line, ſhall be the Vertical Line of the Plain accomodated in like manner to the Apex.

Alſo a right Line perpendicularly erected from the Center of the Earth, to the Vertex of the Horizon, ſhall deſign out (in the Vertical Line) the Vertical Point of the Horizon, called the Zenith; which alſo the concourſe or interſection of the Vertical Line with the hour-line of 12 will effect.

And becauſe below the Horizon, there is nothing in the Heavens further diſcerned, therefore in the Plain nothing is to be deſcribed above the Horizontal Line. wherefore it behoveth the Artiſt to order the Apex of the Gnomon in ſuch a place of the Stile, ſo that all things may be deſcribed upon the Dial-plain in a decent and orderly manner.

In the laſt place, all things depending upon the Apex of the Gnomon, and contained between the Tropicks and the Horizon.

To deſcribe the Azimuth or Vertical Lines.

1. In any Inclining Plain, from the Zenith point of the Horizon noted upon the Plain, deſcribe a Circle, in which (from a Vertical Line drawn upon the Plain, through the foot of the Gnomon) ſet off ſuch Angles as are equal to thoſe Arches found by the firſt Problem, for the right Lines drawn at thoſe Diviſions towards the true Coaſt of the World will be the Vertical Lines.

In an Horizontal Plain.

The equal Angles at the foot of the Gnomon reckoned from the South deſcribe the Vertical or Azimuth Circles.

In any Erect Plain.

The Zenith cannot be fixed, neither can the Vertical Lines meet, therefore there is no need of the computation of the firſt Problem. Only the forming of the Angles at Z, or of the Horizontal Arches, CF, CG, CH, *&c.* is here required. But the Tangents of theſe Angles (the length of the Gnomon being made Radius) ſet from the Foot of the Gnomon towards their due Coaſt, will find points upon the Horizontal Line, by which Perpendicular Lines being let fall will ſupply the places of the Vertical Circles. But every Azimuth or Tenth Circle may be deſcribed from the South, and a number proper there-

to

to aſcribe, *viz.* 10,20,30,*&c.* Or alſo thoſe Select Points anſwerable to the Points of the Marriners Compaſs. Eight whereof complete a Quadrant or fourth part of a Circle, and to the ſame thoſe names may be fixed according as every Nation denominateth them.

Laſtly, All the Uſes of the Vertical Circles may in ſome meaſure be hitherto transferred.

To Deſcribe the Leſſer Circles.

1. *The Parallels of the Equator.*

1. Seek the Diſtance of the Parallel to be deſcribed at every hour (by *Probl.* 2) then making the length of the Gnomon Radius, apply thoſe Tangents to the Hour-lines from the foot of the Perpendicular Stile for where that concourſe or interſection is made, through that point the parallel will paſs. But if a Section appear uncertain or dubious uſe the Appendix of *Probl.* 2. that is, enquire in what Vertical Circle that Section ſhall happen: which being known, if from that part of the Subſtilar Line which is moſt convenient you form the Angle of the Vertical in the foot of the Gnomon, you will have the preciſe Section of the foreſaid Tangent and hour.

By this means are to be deſcribed Parallels.

1. Of the Signs of the Zod.
2. Of the Diurn. Arches.
3. Of the Latitude of Principal Cities, whence you may know, whether the Inhabitants of ſuch or ſuch a Place be *Anthiſcii, Heteroſcii,* or *Periſcii.*
4. The Parallels proper to every Feſtival Day, and ſuch like things.

But the true Parallel proper to any deſigned buſineſs is firſt to be found out, and then to be managed according to the requiſites of *Probl.* 2.

2. *The Parallels of the Horizon, or Almicantheras.*

The Almicanters are to be inſered into the Vertical Lines in the ſame manner as the Parallels of the Equator were into the hour-lines. for the Tangents of the Diſtances (found by *Probl.* 3.) ſet from the foot of the Gnomon (to whoſe length alſo the Tangent is to be limitted) to their proper Verticals, will give the Points through which the Oblique Line repreſenting the Almicanth. is to be drawn: ——But if the Section appear dubious, a remedy for this inconvenience may be uſed from the Appendix of *Probl.* 3. For thence it will appear what Vertical Line numbred, from the Vertical in the Plain V Z, ſhall paſs thro' that ſame Section; Which if (from that part of the Vertical V Z which you ſee moſt convenient) you expreſs in a due Angle framed at the foot of the Gnomon you will have the exact point of Section.

Almicant. deg.	min.	*Umb. ad* *Gnom.*	
84	18	10 *ad*	1
82	53	8	1
81	53	6	1
78	42	5	1
75	58	4	1
71	34	3	1
63	26	2	1
56	19	3	2
53	08	4	3
55	20	5	4
45	00	1	1
38	40	4	5
36	52	3	4
33	41	2	3
30	58	3	5
26	34	1	2

In this manner may be inſcribed every 10 Parallel from the Horizon, thence ſo to be numbered by 10, 20, 30, *&c.* or from them ſome more ſelect, which will ſhew the Proportions of Shadows to their Gnomons: ſuch as are theſe to be Numbred from the Vertex, not from the Horizon.

Of

Of the Hours of other Nations, and how they may be put into Dial-Plains.

The Aſtronomers and Umbreans number equal hours from South to South.

The Egyptians and Romans from Midnight, as we uſe alſo to do in our Civil Account.

To both theſe Computations thoſe hours ſuffice which we before taught how to inſcribe.

The Bohemians and Italians ſtill retain their equal hours, but begin their Numeration from Sun Setting.

The Babylonians and Balearick Iſlands begin from the Sun Riſing.

The Jews were wont to divide every Day (and Night) into 12 Parts, the number whereof among them began at Sun Riſing, and ceaſed at Sun Setting: The hours from Sun Riſing, and Sun Setting are eaſily inſerted; if firſt theſe Parallels of the Diurnal Arches which anſwer to the like number of hours, (*i. e.*) 8, 10, 12, 14, 16, be deſcribed. For the Sun Riſing in the Eaſterly Horizon is the beginning of the hours from the Eaſt. And his Setting in the Weſterly Horizon is the beginning of hours from the Weſt.

If therefore a right Line be drawn through the two firſt Horary Points from the Horizon in any two Parallels, it will be the firſt hour from the Eaſt, or the 23 deg. from Yeſterdays Weſt. And if through the two ſecond Horary Points from the Horizon, a ſecond right Line be drawn, that alſo will be the ſecond hour from the Eaſt, and the 22. from the Weſt; and ſo of all the reſt.

The Jewiſh hours (which are alſo Planetary) are by the ſame artifice inſerted: For if in the Parallels of the Diurnal Arches of the hours of 15 and 9, right Lines be deſcribed through each, there $\frac{1}{4}$ here $\frac{1}{4}$ from the Horizon, they will give the Judaick hours, which alſo will paſs exactly enough thro' the equal hours in the Equator; For, if we look to the exactneſs herein, the Planetary hours cannot be ſhadowed out by right Lines becauſe in the Sphere they are not great Circles.

The End of the Seventh TRACTATE.

Concave and Convex
SPHERICAL and *CYLINDRICAL*
DIALLING.

The Eighth TRACTATE.

FIRST,

Of CONCAVE DIALLING;

SHEWING,

How to draw Hour-lines in the Inſide of any Regular Concave Hemiſphere in any Poſition, either Parallel, Perpendicular, or Oblique to the Axis of the World:

AND ALSO,

To deſcribe the Parallels, Azimuths, Almicantars, and other Furniture into ſuch Concave Dials.

THESE Regular Concave Hemiſpheres, (for of ſuch now we only treat) are the moſt natural Plains upon which Hour-lines may be deſcribed, for that they do ſo naturally repreſent the Sphere, and the manner how the Hour-lines and other Furniture may be inſcribed upon them, is no leſs eaſie, and how both may be effected, ſhall be the Work of this Tractate.

CHAP. I.

To make a Vertical or Horizontal Concave Dial.

HAving a Concave Hemiſphere prepared: as, S N E W. divide the Limb into 4 Quadrants, noted as the former Letters; one of the Quadrants divide into 90 degr. open your Compaſſes to the Quadrant, and ſetting one foot upon E or W. with the other draw the Meridian or 12*th* hour *Figure* I. page 64

S Z N. take out of the Quadrant the Latitude 51 deg. 30 min. and set those degrees upon the Meridian from S. towards Z to P. which P shall be the Pole of the World; then placing your Compasses upon P. (they being opened to a Quadrant) draw the Equator E Æ W. which divide into 12 equal parts; your Compasses being opened as before to a Quadrant, and one foot being placed in those marks made in the Equator, with the other foot describe Circles, which shall be the Hour-lines required; the Stile must be erected in P. with an Angle equal to the Latitude; equal to the length of 60 deg. of the Quadrant, the top must hang over the Centre Z. and be parallel with the Limb, or erect a Style in the Point Z of the same length with the former which shall shew the hour with the Top only.

CHAP. II.

To make an Erect, Direct South or North Concave Dial.

THIS Dial is made altogether like the former, only instead of setting of the Latitude from S to P. you must only set off the Complement of the Latitude, and the Hour-lines only from 6 to 6, are described therein, the rest of the Hour-lines are reserved for a Vertical Dial beholding the North.

CHAP. III.

To make a Meridianal Erect, Direct, East or West Concave Dial.

Figure II. LET the Hemisphere be Z S N G. the Limb being divided into four Quadrants, one of those into 90 deg. From N. upwards, and from S. downwards, set the Latitude to P. then open your Compasses to a Quadrant one foot in P. with the other draw the Circle Q E A. which Semicircle divide into twelve equal parts, your Compass being opened to a Quadrant, one foot placed in each of these marks, with the other draw Circles which shall be the Hour-lines required; as in the Figure. The Style may be a wire laid from P to P. or a wire erected in the Center E equal to the Semidiameter of the Quadrant; for better Instruction see Figure II. which is an East Dial.

page 64

In the same manner is an Equinoctial Dial made, only all the hours from six in the Morning till six at Night, must be drawn, as the rest above those proper for the East or West Dials are, and as the pricked hours 9 8 7 and 6 in the Figure are.

Also the Hour-line of six, *viz.* the Line P. VI. P, must be P 12 P, and the rest numbred as in the Figure is expressed and numbred with Arithmetical Figures.

CHAP. IV.

To make a Vertical, or Erect South or North Declining Concave Dial.

Figure III. YOur Concave being prepared and quartered and marked with the Letters Z N E W, your Compasses being opened to a Quadrant, and one foot in Z or N, draw the Horizontal Circle E S W. take the Declination and prick

page 64 in plain Dialling

prick it down in the Horizontal Line from W to H, one foot of your Compasses remaining in H, being opened to a Quadrant describe the Meridian or hour of XII. in which from Z set off the Complement of the Latitude, or from its intersection with the Horizontal Line set off the Latitude to P, one foot of your Compasses in P, with the other (the Compasses being opened to a Quadrant) draw the Equator Q Æ A, and where it is intersected by the hour of 12, begin to divide it into 12 equal parts, one foot of your Compasses being placed in each of these Points, and being opened to a Quadrant, draw Lines which shall be the Hour-lines required; for the Style, that must be erected in the point P, and the top of it must pass through the Center of the Limb of the Concave and be equal to the length of 60 deg. of the Quadrant, or you may erect the Style in the point S perpendicular to S, the length equal to the former, which will shew the hour of the day with the very top of it: for your better instruction see Figure III.

CHAP. V.

To make a South or North Reclining, Declining Concave Dial.

Figure IV. *page 6*

YOur Concave being prepared as before, quartered and divided, one Quadrant into 90 deg. let the Concave be mark'd with the Letters E W N S. First, draw the Horizontal Line in the Circle S N, from S set off the Reclination to H, one foot of the Compasses in H being opened to a Quadrant, describe the Horizon E M W, in which according to the Declinations from W or E, set off the Declination, and one foot of your Compasses being in that Point with the other describe the Meridian or hour of XII. from M, its intersection with the Horizontal Line in the Meridian set off the Latitude to P, so P shall be the Pole; in P, with the Compasses opened to a Quadrant draw the Equator, and where it's intersected by the Meridian, begin and divide it into 12 equal parts, which you may do by 15 deg. of the Quadrant, your Compasses being opened to a Quadrant, setting one foot in each of these Points, with the other foot describe Circles, which shall be the Hour-lines required; for the Style it must be erected in the Point P, and come to the Center of the Limb, and must be the length of 60 deg. of the Quadrant, or you may as before erect a Style in the Center L, of the same length to shew the hours with its top; for your better instruction behold the Figure.

CHAP. VI.

To make a Polar Concave Dial.

A Polar Concave Dial is no other than an Horizontal Dial in the Latitude of 90 deg. and of all others is most easie to be made, for if you divide the Limb of the Concave Hemisphere into 24 equal Parts, and from the Center of the Hemisphere (by help of a thin Ruler that will bend) draw strait Lines to each of them, those shall be the true Hour-lines.

For the Style, it must be a strait Wire, perpendicularly erected in the Center of the Concave, whose shadow will at all times (the Sun shining) give the hour of the day, and the hours in these Dials must be numbred from XII to XII.

CHAP.

CHAP. VII.

To draw the Hour-lines in a Concave, when the Axis cuts the Hemiſphere into two unequal Parts.

Figure V. LET the Hemiſphere be A B C D, and the Axis A B E, on the Point E deſcribe a Circle, which begin and divide into 24 parts upon ſome Plain, and from the Center E; by thoſe parts draw Lines, which ſhall divide the Circumference A B C D into 24 unequal parts, the Circle C E D muſt be divided into ſuch unequal parts, and they ſhall be the Points by which the hours muſt paſs; then for the finding of the Center by which the Hour-lines ſhall paſs in the Spherical Body, do thus: To find the Centers of 11. or 1. the Hour-line of 11. is marked F G, divide the Circumference betwixt F and G into two parts at H, ſo H ſhall be the Center for the drawing of the Circle of 11, if E be the Pole, but if A and B be the Poles, then the diſtance between F and H, or G and H ſhall be the Centers for drawing of the hours of ſeven and five, by placing one foot of your Compaſſes in 7 or 5, and turning the other foot into the Circle C E D, ſhall give the Center for thoſe Hour-lines; and in like manner you muſt find the Centers for the reſt of the Hour-lines. The Stile, (if A B be the Poles) may be a Wire laid from A to B; but if E be the Pole, then you muſt erect a Wire in the Point E, equal to the length of the Line E B, as is done upon the Plain, or equal to half the length of the Line A B the top of the Style muſt hang over the Point E, and be even with the top of the Concave; ſee the Figure.

CHAP. VIII.

To draw the Hour-lines in a Concave when the Axis doth but only touch the Superficies of the Sphere.

IF the Axis cut the Sphere in one point as P, and the Axis be perpendicular to P; for the drawing of the Hour-lines do thus, divide the Circumference or Limb into 12 equal parts, beginning at P; for the drawing of the Hour-lines divide the ſpaces betwixt P, and the interſections of the Hour-lines in the halves, and thoſe ſhall be the Centers for the Hour-lines: But if the Axis be A P X, then divide the Circle P M into ſix equal parts; then to find the Centers divide the ſpaces betwixt the Pole P, and the Diviſions into halves, and thoſe Points ſhall be the Centers of the Hour-lines; for your better inſtruction behold the Figure.

CHAP.

CHAP. IX.

To describe the Furniture upon Concave Sun-Dials.

SECT. I. *To draw the Parallels of the Sun's Declination,*&c. *in any Concave Dial in which the Axis passes through the Center.*

THE Equator being drawn, set off the degrees of Declination from the Equator in the Meridian of the Plain or Substilar both upwards and downwards; then place one foot of your Compasses in the Pole, and extend the other to those you marked; from the Equator, draw Circles, which shall be the Parallels of the Sun's Declination required, as for example, the drawing two Tropicks, which decline 23 deg. 30 min. from the Equator; take 23 deg. 30 min. and prick it down, in the Meridian both ways, and place one foot of your Compasses in the Pole, with the other extended to the 23 deg. 30 min. describe the two Tropicks, as in Figure I. appears. page 64 in plain dialing

SECT. II. *To draw the Azimuths or Vertical Circles.*

DIvide the Horizon into 180 deg. beginning where it's intersected by the Meridian, if you would draw every 10 Azimuth, then you may only divide it into 18 equal parts, beginning at the same place; but if you would only draw every 15 Azimuth, then divide the Horizon into 12 parts, beginning as before at the Meridian; if you would draw the Points of the Compass, divide the Horizon into 16 parts, then open your Compasses to a Quadrant, place one foot in any of those Divisions, where the other foot intersects the Horizontal Line shall be the Center for drawing that Azimuth.

SECT. III. *To draw the Almicanthers.*

HAving found the Points of *Zenith* and *Nadir*, the distance of these Points to the Horizontal Line into 90 deg. one foot being placed on one of those Points, the other extended to those degrees, Circles drawn from one Tropick to another shall give Almicanthers or Circles of Altitude.

The Proportion of the Shadow to a Gnomon may also be drawn on the same manner.

SECT. IV. *To draw the Planetary or unequal Hours in any Concave Dials.*

FOr the drawing of the Planetary or unequal hours, having first described the Horizon, Equator, and the two Tropicks, divide that part of the Tropick which is intercepted betwixt its intersection with the Horizontal Circle, into 12 equal parts beginning at 12, the Equator being before divided into 12 equal parts by the Hour-lines, open your Compasses to a Quadrant,

one foot being placed in one of thoſe Diviſions, move the other foot until you find the Center, which will draw both thoſe Points into one Circle, and draw Circles which ſhall be the unequal hours required.

SECT. V. *To draw the Hours from Sun Riſe to Sun Set, called the* Italian *and* Babyloniſh *Hours.*

PLace one foot of the Compaſſes in the Pole, and extend the other to the interſection of the Horizon and Meridian, and deſcribe the Parallel of the Latitude, which ſhall be divided into 24 equal parts by the Hour-circles, place one foot of your Compaſſes in each of thoſe Diviſions (the Compaſſes being opened to a Quadrant) the other foot being placed within the Circle of the Latitude; in the Hour-circle which paſſes through the Point where the Compaſſes is ſet in the Circle; making that the Centre deſcribe Circles from one Tropick to another, which ſhall be the Hour-lines from Sun Riſe to Sun Set; and ſhall paſs by the Interſection of the Hour-lines and the Equator.

You may alſo draw the *Circles of Poſition*, the *Signs* in the *Meridian*, the *Signs aſcending and deſcending*, the *Circles of Longitude*, with many other, as the *Parallels of the length of the Day and Night*, the *Parallels of the Sun's Riſings* and *Settings*, the *Day of the Month*, and the *Zodiack*.

SECT. VI. *To draw the* Equator, Parallels *of* Declination, *&c. in a Concave Dial, when the Axis cuts it into two Unequal Parts, or at Oblique Angles.*

ON that Point of the Axis which you aſſign for the Center of the World deſcribe a Trigon of the Signs, or Parallels of Declination, &c. ſo the middle Point upon the Limb betwixt thoſe Interſections ſhall be the Centers for the deſcribing of the Parallels, &c.

I ſhall not need to give Examples, or make any Scheme for the farther illuſtrating of what I have here ſaid concerning the inſcribing of the Furniture into theſe Concave Dials, for what hath been already delivered in the Fourth, Fifth and Sixth Tractates, and that which followeth in the Ninth, Tenth and Eleventh Tractates, will make it very obvious to the meaneſt Capacity, and ſo I will conclude this of Concave Dialling.

SECOND-

SECONDLY,

Of CONVEX DIALLING;

SHEWING,

How to make a Dial upon the Convex Superficies of a Globe, which ſhall ſhew the Hour by the Shadow, which ſeparateth the Enlightned Hemiſphere from the Opacous.

THE Performance hereof is very eaſie, for (the Globe being truly Spherical) if the *Equinoctial Circle*, the two *Tropicks*, and (if you pleaſe) the two *Polar Circles*, which will be neceſſary for ornament only to be deſcribed thereon, and the *Equinoctial* divided into 24 equal Parts, and Points, or Stars, or other marks there made, they ſhall be the true Hour-points: And if this Globe be ſet upon a Neck or *Pedeſtal*, and the Poles of the Globe ſo elevated and depreſſed as to reſpect the real Poles in the Heavens, and one of the Hour-points, which muſt have the Number VI. ſet to it, to behold the Meridian of the Place, then will the two XII. of Clock Hour-points behold one the Eaſt, and the other the Weſt Parts of the Horizon; And then the Sun at all times ſhining upon the Globe, will Enlighten one Hemiſphere, and the other will be Shadowed, and where the Line of Shadow falleth amongſt the Hour-points upon the Equinoctial, it ſhall there ſhew the hour of the Day in two places; namely, one on the Eaſt, and another on the Weſt Side of the Globe. And let this ſuffice for Convex Sphericals.

THIRDLY,

Of CYLINDRICAL DIALLING,

EITHER

CONVEX or *CONCAVE*.

I. *Of thoſe that fall in a Right Sphere,* i. e. *ſuch as lie Parallel to the Axis of the World, and their Baſes Parallel to the Equinoctial.*

HOur-lines may be drawn upon thoſe Cylinders with great eaſe and facility, although in them there may be various Poſitions of the Axis.

I. *If the Axis fall in the very Centre of the Baſe of the Cylinder*; Then, divide the Circumference of the Baſe of the Cylinder into 24 equal parts, and draw Lines from the Centre to each of thoſe Points, which ſhall be the Hour-lines for the Baſe of the Cylinder: —— And where thoſe Lines cut the Circum-

Circumference, Lines drawn from them down the Cylinder's Side, they ſhall be the true Hour-lines, which will be all parallel each to other.

II. *If the Point of the Axis fall not juſt in the Center of the Baſe of the Cylinder.* Through that Point where the Axis falls, and the Centre of the Cylinder draw a line, and with a pair of Compaſſes take the neareſt diſtance from the Axis-point to the Circumference of the Cylinder, and with that diſtance upon the Axis-point deſcribe a Circle, which divide into 24 equal parts, (beginning at the Diameter firſt drawn) Lines drawn from the Axis-point through every of them, and extended to the Side or Circumference of the Baſe of the Cylinder ſhall be Hour-lines, and again Lines drawn from them down the Side of the Cylinder ſhall be Hour-lines alſo.

III. *If the Point of the Axis fall in any part of the Periferie of the Cylinder's Baſe.* Then divide the Circumference of the Cylinder's Baſe into 12 equal parts, beginning at the Axis-point; Lines drawn from thence to the ſeveral Points in the Periferie of the Circle, and alſo down the Cylinder's Side, they ſhall be the Hour-lines.

IV. *If the Axis-point fall without the Baſe of the Cylinder.* Then the diſtance between that Point and the neareſt part of the Periferie of the Cylinder's Baſe being made Radius, and a Circle (or Semicircle) be thereon deſcribed, and divided into 12 equal parts; then Lines drawn from the Axis-point, through thoſe Diviſions ſhall each of them cut the Periferie of the Cylinder's Baſe in two Points, from which Lines drawn from one to the other (each to his correſpondent) they ſhall be Hour-lines, and from thoſe Points, Lines muſt be drawn down the Side of the Cylinder alſo.

More might be ſaid concerning drawing Hour-lines, and other Furniture alſo, upon Cylinders, and other Solid Bodies either Regular or Irregular, as alſo of Rings, Quadrants, Parallelograms and other Dials, which give the hour, *&c.* by help of the Sun's Altitude, the making whereof is ſo well known to every Artificer, and Maker of Mathematical Inſtruments, that nothing more of it need be ſaid in this place. And beſides the Precepts delivered in the Fourth, Fifth, Sixth, Ninth and Tenth Tractates hereof are ſo ample, that it were but *Actum agere*, to ſay any thing more concerning theſe Matters: And ſo I conclude this Tractate.

The End of the Eighth TRACTATE.

PRO-

PROJECTIVE DIALLING:

CONTAINING,

Several General and most Easie Ways to *Project* *Hour-Lines* upon all kinds of *Superficies*, whether *Plain* or *Carved*; *One* or *Many*; *Contiguous* or *Separate*: and that without any regard had to their *Situations*, either in respect of *Declination*, *Reclination* or *Inclination*.

AND ALSO,

How to insert all usual *Furniture* into *Sun-Dials*, drawn upon such *Superficies*; by the Joynt Use of the *Horizontal Projection* or *Planispheres*, and a *Semicircle* or *Quadrant* fitted for those Performances.

The Ninth TRACTATE.

PROEME.

THE *Precepts* in this following *Tractate* delivered, most of them (with little alteration) are the *Inventions* and *Practices* of the late Learned and Industrious Mr. *Samuel Foster*, sometime *Astronomical Professor* in *Gresham College* in *London*; and some of them were Printed, *Anno* 1659. in his *Posthumous Miscellanies*: And others of his (not there Printed) are here added, as they were transcribed out of a *Manuscript* of his, which (for the excellency of many things therein contained) he Entituled *GOLD*. Those which I found there concerning *Projective Dialling* are here inserted: and others which concern *Reflective* and *Refractive Dialling* shall come in their proper places.

The *Precepts* in this *Tractate* being performed (for the most part) *Mecanically* and by *Instrumental Operation*, and not by *Geometrical Protraction*; apt and proper *Schemes* or *Diagrams* cannot be expected to every distinct *Chapter* or *Section*, for that, to the Ingenious would be unnecessary: And besides, it is supposed the Reader to be already acquainted (at least, in part) with what hath been delivered in the foregoing *Tractates*; and then, the *Precepts* themselves, without *Examples* will be sufficient for the understanding of what shall be deliver'd in this *Tractate*: Notwithstanding, There are in several places Illustrative *Schemes* inserted, by which, whatsoever is there only verbally expressed, may be occularly discerned; nay, I may aver, will give more light to the Ca-

of those numbers, and write them in the sixth Column, under the numbers there already placed, you shall then have the lengths of the Semidiameters of the same several Parallels. And lastly, if from each of these Semidiameters, you take the Tangents of the fourth Column, which were before translated and are already standing in the sixth Column, every couple as they stand, then shall you produce the distances of the Centers of every Parallel, from the Center of your Projection, which is the thing now required. And so the numbers of the second Table are made up also.

See here the Form of the whole Calculation.

The First Table.

	Arches	*Halfs*	*Tangent*	*Diamet.*		
♋	28.00 105.00	14.00 52.30	24932 130322	155254	24932 77627	♋
♌	31.17 108.17	15.38 54.00	27983 138313	166296	27983 83148	♊
♍	40.00 117.00	20.00 58.30	36397 163185	199582	36397 99791	♉
♎	51.30 128.30	25.45 64.15	48234 207321	255555	48234 127777	♈
♏	63.00 140.00	31.30 70.00	61280 274747	336027	61280 168013	♓
♐	71.43 148.43	35.51 74.21	72255 356956	429211	72255 214605	♒
♑	75.00 152.00	37.30 76.00	76732 401078	477810	76732 238905	♑
1 *Col.*	2 *Col.*	3 *Col.*	4 *Col.*	5 *Col.*	6 *Col.*	

The Second Table.

Tab. of Centers.		*Tab. of Intersect.*	
52695	♋	♋	24932
55165	♊	♌	27983
63394	♉	♍	36397
79543	♈	♎	48234
106733	♓	♏	61280
142350	♒	♐	72255
162173	♑	♑	76732

How to make the Table of Interſections, and of Centers more fully.

1. TAKE half the complement of your Latitude, and comparing it with 33 deg. 15 min. find out both the ſum, and difference of them, and ſet this ſum and difference in the uppermoſt cell of the Arches anſwering to *Cancer* 00 deg. and for better diſtinction, note them with A and B. Theſe two numbers are for the firſt point of *Cancer*, and are as Radical Numbers, by help of which all the reſt are made.

2. To theſe two numbers A and B, add ſuch numbers of the Table following as do ſtand at ſuch degrees (of every Sign) as you intend to put into your projection (as in a large one of 30 inches diameter, you may inſert every degree, or each two degrees for one of 15 inches, or each third degree for 10, or each fifth degree for ſix inches diameter) and place each couple of theſe laſt Products in one cell, ſo ſhall you make up the column of Arches, ſuch as in the following Table made for the Latitude of 51 deg. 30 min. to the beginning of each Sign, only for an example.

3. For theſe Arches of the firſt column, ſet the Tangents belonging thereto, as appeareth in the ſecond column by the numbers C and D, *&c.*

4. Then for the third column of Diameters, and Semidiameters, it is thus perfected, add the two Tangents ſtanding together in each cell, and put the ſum of them in the third column, in the ſame line with the uppermoſt of the ſecond column; So ſhall theſe ſums be the Diameters of ſuch Parallels in the Projection as do paſs through the above-mentioned degrees, choſen for the Projection. So C D added together, make E: G H make I: L M make the number N, *&c.*

5. If half theſe Diameters be taken, by a Bi-ſection of the Diameters before found, the ſame will be the Semidiameters, and are to ſtand in the ſame third column, as the ſecond line in each cell ſheweth; So E being Bi-ſected makes F, I makes K, N makes O, *&c.* From theſe thus prepared the two fore-mentioned Tables will eaſily be excerpted in this manner.

6. The inferiour Tangents of each cell in the ſecond column, are the very numbers which do make up the Table of Interſections. If therefore, they be only tranſcribed, you ſhall have the ſame Table perfected, as H M, *&c.* in the ſecond column being tranſcribed, will make up P Q R, *&c.* the full Table of Interſections.

7. The differences of the inferiour numbers of the ſecond and third columns, being gathered into the particular cells of the Table of Centers, do make up the numbers of that ſame Table; So D taken from F, makes S: H taken from K, gives T: and M from O, makes V: *&c.* And thus are the two Tables to be made up.

A Table for the Horizontal Projection, made to the Latitude of 51 Degrees 30 Minutes, ſhewing where every Parallel that paſſeth through each Degrees of the Ecliptick is to cut the Meridian Line.

The Table of Interſections.

	♋	♌	♍	♎	♏	♐	
0	2493	2802	3640	4823	6128	7226	30
1.	2493	2826	3676	4867	6172	7252	29
2	2493	2842	3709	4910	6212	7259	28
3	2496	2864	3746	4953	6253	7306	27
4	2500	2886	3782	4997	6297	7332	26
5	2503	2908	3819	5040	6338	7359	25
6	2506	2931	3855	5084	6379	7382	24
7	2512	2956	3892	5128	6420	7404	23
8	2515	2981	3929	5169	6457	7427	22
9	2521	3003	3966	5213	6498	7449	21
10	2527	3029	4006	5258	6540	7467	20
11	2537	3057	4047	5302	6577	7490	19
12	2543	3083	4084	5347	6615	7508	18
13	2552	3108	4122	5388	6652	7522	17
14	2561	3137	4163	5433	6690	7540	16
15	2571	3166	4200	5479	6728	7558	15
16	2583	3195	4241	5500	6766	7572	14
17	2596	3224	4283	5566	6805	7586	13
18	2608	3252	4321	5608	6839	7600	12
19	2620	3281	4362	3654	6873	7609	11
20	2633	3314	4404	5696	6911	7623	10
21	2645	3343	4445	5739	6946	7632	9
22	2661	3375	4487	5785	6976	7641	8
23	2676	3404	4526	5828	7011	7646	7
24	2692	3437	4568	5871	7046	7655	6
25	2708	3469	4610	5914	7076	7659	5
26	2726	3502	4653	5957	7107	7664	4
27	2745	3538	4695	6001	7137	7669	3
28	2764	3571	4738	6044	7168	7673	2
29	2783	3607	4781	6084	7199	7673	1
30	2802	3640	4823	6128	7226	7673	0
	♊	♉	♈	♓	♒	♑	

The

The Table of Centers, for the Latitude of 51 Degr. 30 Min.

This Table ſheweth how far the Centers of every of the former Parallels, are from the Center of the Horizontal Circle in the Horizontal Projection.

	♋	♌	♍	♎	♏	♐	
0	5269	5519	6339	7954	10673	14235	30
1	5269	5535	6380	8026	10789	14342	29
2	5269	5554	6418	8099	10897	14451	28
3	5272	5573	6460	8173	11006	14562	27
4	5274	5593	6502	8249	11129	14674	26
5	5277	5612	6545	8326	11243	14787	25
6	5279	5631	6589	8404	11359	14883	24
7	5284	5654	6633	8484	11477	14980	23
8	5286	5677	6678	8558	11586	15078	22
9	5291	5697	6724	8641	11709	15177	21
10	5296	5720	6775	8726	11834	15258	20
11	5203	5746	6826	8812	11949	15359	19
12	5308	5770	6874	8899	12066	15441	18
13	5315	5794	6922	8981	12185	15503	17
14	5323	5820	6976	9072	12306	15587	16
15	5330	5849	7026	9165	12430	15670	15
16	5340	5876	7082	9252	12556	15735	14
17	5350	5904	7138	9348	12684	15799	13
18	5359	5933	7191	9438	12800	15864	12
19	5369	5961	7249	9538	12918	15907	11
20	5379	5994	7308	9682	13053	15973	01
21	5390	6023	7369	9727	13175	16017	9
22	5402	6056	7430	9833	13284	16061	8
23	5415	6086	7487	9932	13411	16083	7
24	5428	6120	7550	10034	13539	16128	6
25	5440	6154	7615	10137	13653	16150	5
26	5456	6189	7680	10242	13770	16172	4
27	5472	6228	7747	10349	13888	16195	3
28	5487	6263	7815	10458	14007	16217	2
29	5503	6303	7884	10560	14129	16217	1
30	5519	6339	7954	10673	14235	16217	0
	♊	♉	♈	♓	♒	♑	

Thus

Thus are theſe two Tables to be made up.

	Arches.	*Tangents.*	*Diameters and Semidiameters.*	
♋	A 52.30 B 14.00	C 130322 D 24933	E 155255 F 77627	♋
♌	X 54.09 X 15.49	G 138399 H 28015	I 166414 K 83207	♊
♍	Y 54.30 Y 20.00	L 163185 M 36397	N 199582 O 99791	♉
♎	Z 64.15 Z 25.45	207321 48234	255555 127777	♈
♏	70.00 31.30	274748 61280	336028 168014	♓
♐	74.21 35.51	356957 72255	429212 214606	♒
♑	76.00 37.30	401078 76733	477810 238905	♑

	Interſections	*Centers*	
♋	P 24933	S 52694	♋
♌	Q 28015	T 55192	♊
♍	R 36397	63394	♉
♎	48234	79543	♈
♏	61380	106734	♓
♐	72255	142351	♒
♑	76733	162173.	♑

Præcepta ſuperiora, characteribus compendioſè expreſſa.

33 Deg. 15 min. $\pm\frac{1}{2}$ Complement Latit. $=\frac{A}{B}$

$\frac{A+}{B+}$ b, c, d, &c. in tab. ſequ. $=$ X, Y, Z, &c.

Quorum arcuum Tangentes ſunt C,D,G,H,L,M, &c.

$C+D=E.\quad G+H=I.\quad L+M=N$, &c.

$\frac{E}{2}=F.\quad \frac{I}{2}=K.\quad \frac{N}{2}=O$, &c.

$D=P.\quad H=Q.\quad M.=R$, &c. Atque hæc eſt tabula Interſectionum.

$F-D=S.\ K-H=T.\ O-N=V$, &c. Atque hæc eſt tabula Centrorum.

And here, it muſt not be forgotten; that the Precepts of making up theſe Tables, are proper to thoſe Latitudes that exceed 23 deg. 30 min. for in thoſe Latitudes, which are leſs than 23 deg. 30 min. ſome North Parallels will not interſect upon the South part of the Meridian at all, but altogether upon the North, and then, for ſuch Parallels, their North Declinations muſt not be taken out of the Latitude, but the Latitude out of them, and ſo the Superiour Arches of the ſecond Column will at firſt decreaſe in ſuch Latitudes, and after again increaſe, and the Diameters in the firſt Column (for ſuch Parallels as are altogether North, of which only we now ſpeak) muſt be made by the Differences (not Sums) of the Numbers of the fourth Column; And the Sums (not Differences

rences) of the Numbers in the Sixth Column, give the Diſtances of the Centers of ſuch Parallels we now mention, from the Center of the Inſtrument. Now to know how many degrees of Declination will interſect both Lines on the North ſide of the Meridian, in a North Latitude is eaſie: Namely, all thoſe Parallels whoſe Declination from the Equinoctial is greater than the Latitude, and none elſe. And for thoſe only, all this caution is made; The reſt of the Table for other Parallels muſt be finiſhed as before preſcribed, and what is true here of North Latitude, and North Parallels, is reſpectively true of South Latitude, and South Parallels.

SECT. III. *The Delineation of the Parallels upon the Inſtrument.*

AFter you have deſcribed the Circle upon the Horizon (which is to contain the whole Work) and quartered the ſame, and ſet out partitions for the limb, to divide it as the uſual manner is into 360 deg. you are to make a *Decimal Scale* of the ſame length, with the innermoſt Semi-Diameter of your Inſtrument, for this Scale by help of your Tables will pitch out the whole Work.

For looking firſt into your Table of Interſections, ſee what the firſt Number there is, namely, 24932, take this in your Compaſſes upon your Decimal Scale from 2 forward, as the Letters of *a* and *b* do declare; the ſame length of *a b* will reach upon the South part of the Meridian, from Z the Center of your Inſtrument unto A upon the Meridian Line, which gives the Point of Interſection between the Parallels of ♋, and the Meridian. So the ſecond Number being taken in your Compaſſes from the Decimal Scale, will give the length Z *c*, ſhewing where the Parallel of ♌ and ♊ is to paſs through the Meridian. The third Number ſo ordered, will give the Point *i*, the fourth *o*, the fifth *u*, the ſixth *m*, and the laſt will give *x*, where the reſt of the Parallels of ♍ and ♉, ♎ and ♈, ♏ and ♓, ♐ and ♒, and laſtly ♑, muſt interſect with the Meridian.

After theſe Points of Interſections, you are next to prick down your Centers anſwering to them. For the firſt Number in the Table of Centers being taken from the Decimal Scale, and pricked down upon the North part of the Meridian from Z (towards N) and it will reach to A. And ſo the ſecond Number will be extended from Z to E, the third from Z to I, the fourth to O, and the fifth to V, the ſixth to M, and the ſeventh and laſt to X.

Having gone thus far, the reſt will be eaſie; For if you ſet your Compaſſes from A, the firſt Center, to *a* the firſt Interſection, you may deſcribe the firſt Parallel of *Cancer*: And ſo if from E the ſecond Center, you extend to *e* the ſecond Interſection, you ſhall deſcribe the ſecond Parallel paſſing through *e*: and ſo forward with the reſt, having due regard to every Interſection, with his proper Center: And thus are the Parallels to be deſcribed, amongſt which that which paſſeth through *o*, is the Æquinoctial, and if it be true done, will paſs through W and E, each tenth Parallel muſt be diſtinguiſhed with ſomewhat a bigger Line than the reſt, and where every fifth or third will not come in for want of due ſpace, as about *Cancer* and *Capricorn*, where they grow cloſe, there may you put in every fifth or tenth only, which will ſerve in thoſe narrow ſpaces as well as more.

SECT. IV. *The Delineation of the Hour Circles.*

First, you must prick down the North Pole (which in our supposition is elevated 51 deg. 30 min.) in this manner. Take the Complement of the Latitude, *viz.* 38 deg. 30 min. and half it, which will be 19 deg. 15 min. seek then the Tangent of 19 deg. 15 min. you shall find it to be 34921, take this upon your Decimal Scale, and prick it upon the North part of the Meridian from Z, towards N, you will find it to fall in P, that Point P therefore is the North Pole in this Projection, through which all the Hour-circles now to be drawn must pass.

The first hour Circle to be described is the hour of six, upon which all the rest have their dependance; now to effect this, you are to look for the Secant of your Latitude (which is as before 51 deg. 30 min.) which will be found to be 160638, this Number taken out of the Decimal Scale must be extended upon the South end of the Meridian from P, and you shall find it will reach unto B; upon B therefore as your Center with the distance B P, describe the Hour-circle of 6, which, if all be right, will pass through the Points of E and W exactly, where the Equinoctial also cutteth, if it be justly described; now through the Point B, with the Center of this hour of 6, draw the infinite Line C B D, both ways perpendicular to the Meridian Z S B, for upon this Line shall stand all the Centers of the other Hour-circles, which to design you are to work thus:

Make a second *Decimal Scale*, equal in length to B P, the Semidiameter of the hour of 6, then by help of the Canon of Tangents, take out of this Scale, first, the Tangent of 15 deg. or 1 hour, which will be 26794, and prick it down upon the infinite Line C D, both ways from B to F, and from B to G; Again seek the Tangent of 30 deg. which is 57735, and take it in the same Scale, and prick it down upon the Line C D, both ways to H and I; Thirdly, seek the Tangent of 45 deg. 100000, which set as before, will just reach to C and D. Then fourthly, the Tangent of 60 deg. 173205 will so reach to K and L: Lastly, set the Tangent of 75 deg. which is 373205, from B to R, and from B to T. This done, if now you set one foot of your Compasses in F as Center, and open the other to the Point P in the Instrument, you shall describe the Hour-circle of 7, on the East side of the Meridian, and carrying one foot with the same extent unto G, will reach unto P again, which swept on the other side, will describe the hour of 5. So also in the same manner may you describe from H and I, as two Centers of the hour, of 8 and 4, passing through the same Point P; And upon the Centers C and D as before, you may describe the hours of 9 and 3; * And from K and L, the hour of 10 and 2. Lastly, from R and T, the hours of 11 and 1, all which are exactly to pass through P the Pole; And so the like is to be done for the half hours, &c.

* *The Line* C D *is supposed to be infinitely extended from* B, *both ways, and therefore (for want of room in this place) the Letters* R K *and* L T *could not be in this Figure placed according as their true Tangent distances do require.*

Thus have we done with those Lines which do properly belong to the Projection: but because the Instrument, if it pass thus, will not perform all the uses for which it is intended, I have therefore added other Lines to it, which may well stand without defacing any of the Work, the description whereof is in brief, as followeth.

SECT. V. *The Description of what Lines are added to the Projection, which vary not with the Latitude, as the Projection it self doth.*

COunt from N to ♋ and ♋, both ways upon the Limb, the Sun's greatest Declination 23 ½ deg. and draw the Chord ♋ ♋, then look the Secant of 23 deg. 30 min. in the Canon of Secants, which will be found 109044; take this upon your first Decimal Scale, and prick it down upon the Meridian from Z to *h*, then again setting one foot of your Compasses in *h*, open the other to ♋, and describe the Arch ♋, ♈, ♑.

Again, Having obscurely drawn the cross Diameter of East and West, take so much of it as may conveniently be used on both sides the Center, namely, Z ♋, and divide it into 11 equal parts, and of the same equal parts let Z ♈ upon the Meridian contain 12, then draw the two strait Lines ♈ ♋, on both sides of the Meridian: these may be called the Triangular Lines, to distinguish them from the rest: Thus are all the Lines to be drawn, now follows the manner of their Division.

SECT. VI. *The Division of the Triangular Lines.*

DIvide each of those Lines first into two equal parts at *b* and *d*: then again divide each of those halfs *b* ♈ *b* ♋, *d* ♎, *d* ♋ into 45 such parts as a Tangent Line of 45 deg. or a *Radius* of that length would require, so shall each of the whole Lines contain 90 parts, unto each 30 Division whereof are the Characters of the twelve Signs to be set.

SECT. VII. *The Division of the Arch and Chord.*

ON the Limb of your Instrument, number the Complement of Latitude from N to *p*, and draw the infinite Line Z *p*, then prolong the Chord ♋ and ♑ both ways, so shall it meet with Z *p*, at *n*; Now to the *Radius b n*, describe the Semicircle *n k r*, cutting the Meridian extended at *k*, and divide this Semicircle into 180 equal parts, or degrees; which done, if you first draw right Lines from each degree thereof to the Center *b*, and beyond, till it cross through the Arch divided in the Instrument, (as you see each 30th degree in the Scheme doth) you shall by that means divide the Arch into its proper parts. Secondly, if from each degree on both sides *k*, you draw Lines parallel to the Meridian of the Instrument Z *k*, till they cut through the Chord, they will so divide the Chord into its requisite parts. *The Line* r n, *is a Line of Versed Sines.*

Hitherto have you near had the whole description of the Instrument it self in every part, after which all superfluities being first drawn away, you must affix such Characters and Figures as are necessary to help you in your several Accounts; to the effecting whereof, the Picture it self will be of sufficient direction, and much better than many Words.

SECT. VIII. *Of the Ruler.*

THere remains only a Ruler to be fitted to the Instrument, the breadth whereof may be as you will, about the 10th or 12th part of the length, and the length to reach over as a Diameter to the whole Planisphere, you must take care that the fiducial edge be very strait, and at the middle of it a little Semicircle left, whose Center A, being truly placed, upon the very middle Point of the fiducial Line must be pierced through with a small hole, that so it may be fixed through it, to the Center of the Instrument at Z. Next of all, you are to fit the Ruler for the Graduation, which is done by drawing two Lines parallel to the fiducial edge; one very near it to receive the degrees, the other farther off, to receive the Figures for Distinction, and Numeration.

For the Graduation of it, set off the length A B both ways from A, equal to Z N, the Semidiameter of the innermost Circle of the Planisphere, which is also equal to your first Decimal Scale; then the easiest way to graduate it will be by the joynt help of the Canon of Tangents, and your Decimal Scale, in this manner; look into the Canon for 45 deg. and it will be 100000, equal to the number of the whole Scale, and those are signified upon the Ruler already by A B, A B; then look half a degree less, namely, 44 $\frac{1}{2}$ whose Tangent is 98269, take that out of your Decimal Scale with your Compasses, and setting one foot in A, with the other draw the first Division, between the edge and the parallel Line next to it, upon both sides the Center A; Then again, Look the Tangent of half a degree less, *viz.* 44, whose Tangent is 96568, which take off, and set it both ways from A, as before, and thus proceed by half degrees till you have gone down through the forty five first whole degrees of the Canon, and then you shall find that you have inscribed twice 45 degrees, that is 90 parts upon each half of the Ruler, which represent such degrees as here are required, every 10th and 15th of them must be distinguish'd from the rest with a longer Line, and numbred inwards towards the Center by 10, 20, 30, *&c.* to 90, as in the Figure sufficiently appeareth. After this is ended, you are to pin down the Ruler to the Instrument, as is before shewed, and then will your Planisphere be fitted to the uses which now follow.

CHAP. II.

An Explanation of the Circles, and Lines in the Projection.

THE Limb of the Planisphere representeth the Horizon of the place for which it is made; The Diameter N S stands for the Meridian whose Sections with the Horizon at N S, signifie the North and South Points of the same Horizon, and the Points W and E, being each a quarter of the Circle distant from the former, do represent the Points of East and West, and a Diameter drawn through them and the Center, is the prime Vertical or East and West Azimuth; The Center noted with Z, signifies the Zenith or Pole of the Horizon. The Ruler therefore, being fixed thereto, shall represent any Azimuth, or Vertical Circle, all which do pass through the Zenith Point, and the degrees and numbers upon the Horizon, will shew what Azimuth from North or South; the Ruler being fixed at any place doth represent.

repreſent. The degrees upon the Ruler denote the degrees of any, or all the Azimuths, and ſo perform the Office of Almicanthers, or Parallels of Altitude above the Horizon.

Within the Projection it ſelf, the Point P upon the Meridian ſignifies the North-Pole, and all the Circular Lines meeting there, (but ſpreading over the whole Superficies) are the Meridians of the Sphere ſuch as ſtand for the hours of the place, according whereunto they have their Figures ſet upon them, ſhewing what hour each of them ſtand for.

The Parallels which croſs through the Meridian, or Hour-circles, are the Diurnal Arches of the Sun at ſeveral times of the year; There are ſo many of them drawn as the Inſtrument will well contain, the reſt muſt be ſupplied by imagination to paſs between them that are drawn; even ſo many as may anſwer to every degree of the Ecliptick. And according to that ſuppoſition, each 30th deg. or Parallel hath ſuch Characters, or Signs annexed unto it, as it doth cut through in the Ecliptick, and the intermediate Lines ſtand for thoſe 30 Parallels that paſs through the 30 degrees of each Sign, and accordingly muſt be eſtimated, and numbred.

The other Lines which are inſerted, are not properly of the Projection, neither ſhall any explication of them be needful, more than when it is treated to ſhew the uſe of them.

CHAP. III.

The Uſe of the Planiſphere, digeſted into ſeveral Propoſitions.

SOme of the Propoſitions of this Chapter have been delivered by others, what I have added of my own, or omitted of theirs, may eaſily be found by comparing their Books with this. Their only purpoſe being barely to perform theſe things upon the Inſtrument, and to go no farther; that uſe indeed may be made of this Chapter, but my intent is beyond theſe, for that which is here performed is premiſed only, and prepared for what is to be done in the next Chapter, which is the only aim and ſcope, which theſe three firſt Chapters drive at.

SECT. I. *To find the Degree of the Ecliptick that the Sun is in every day, and the Parallel belonging to it.*

YOu may know the degree of the Sun in the Ecliptick (if no better way) well enough for your purpoſe by remembring the day upon which in every Month it entereth into the ſeveral Signs, and allowing the motion of it, to be one degree every day, ſo ſhall you know how many degrees it is gone into any Sign, or how many degrees it wants to come to the beginning of the Sign, as *Aug.* 7th I know the Sun entreth into ♍ the 13th day, and that the 7th day wants ſix days of the 13th: Therefore I conclude the Sun to want ſix degrees of ♍, and ſo to be in the 24th of ♌; And again, for *Aug.* 16, becauſe 16 is three days more than 13, (the day of the Sun's entrance into ♍) therefore I ſay that the Sun is in the third degree of ♍: And theſe Notes give (near) their beginning, *Jan.* 11 ♒, *Feb.* 8 ♓, *March* 10 ♈, *April* 10 ♉, *May* 11 ♊, *June* 11 ♋, *July* 13 ♌, *Aug.* 13 ♍, *Sep.* 13 ♎, *Octo.* 13 ♏, *Nov.* 12 ♐, *Dec.* 11 ♑,

Then to find the Parallel for 7th of *Auguſt* is not hard; For if you remember every Sign hath 30 Parallels upon the Planiſphere, (either expreſſed or to be ſuppoſed, or ſupplied by imagination) you may accordingly find where the 24th Parallel from ♌ to ♍ is to be placed, and ſo imagine a Line to run all along even with the reſt, and the ſame ſhall be the Parallel of the day, and the like may be done for all the days of the Year.

SECT. II. *At any time to find the Sun's Azimuth.*

fig. page 12

OBſerve the Sun's Altitude, or in what Almicanther the Sun is by a Quadrant, or otherwiſe, as is ſhewed in the fourth Chapter by the Semicircle, count this Almicanther or Altitude upon the Ruler, and (keeping it upon the due Coaſt from South, either Weſtward, or Eaſtward, according as you made your obſervation either in the Morning or Evening) move it till the Altitude thereon numbred, do meet with the Parallel of the day whereupon your obſervation was made, and there fix it, ſo ſhall it lie in the ſame Azimuth wherein the Sun at the time of obſervation was, and the Numbers in the Horizon or Limb, will give you how many degrees that Azimuth is from the South, if it ſhall be required: Example, at *London*, Latitude $51\frac{1}{2}$, obſervation made *Aug.* Seventh, the Sun in ♌ 24, Altitude 35 Evening, Parallel ♌ 24, Azimuth $65\frac{1}{8}$.

SECT. III. *To find at what Altitudes above, or Profundities (or Depreſſions) under the Horizon, every Hour-circle cuts upon any Azimuth.*

THe Ruler being laid to the Azimuth, as in the former Propoſition, or otherwiſe, will ſhew the things required of it ſelf. As ſuppoſing the Azimuth to be $65\frac{1}{8}$ from South toward the Weſt, as was now found out, then ſhall the hours above the Horizon cut thoſe number of degrees and minutes. Namely, 12 cuts 90, as it ever doth, 1 cuts 79, 2 cuts 63, 3 cuts 43, 4 cuts $17\frac{1}{2}$ deg. and theſe are to be accounted Altitudes above the Horizon: then out of the other part of the Ruler, 5 cuts 7 deg. 6 cuts $27\frac{1}{2}$, 7 cuts $42\frac{1}{2}$, 8, 53, 9, 63, 10, $71\frac{1}{2}$, and 11 cuts 80 deg. below the Horizon. And note ever, that from the Center of this Inſtrument towards that part of the Ruler whereon the Altitude of the Sun, and parallel for the day do interſect, I ſay on that half of the Ruler the Interſections of the hours are to be accounted Altitudes from the Horizon to the Zenith of thoſe very hours that do interſect: On the other part of the Ruler the Sections are to be eſteemed Depreſſions, or Profundities under the Horizon down to the Nadir, not of thoſe hours that do interſect the Ruler on that Coaſt as they are placed on the Inſtrument, but of their oppoſite hours in the contrary part of the Heavens; which they may well do becauſe each oppoſite hours are equal in this reſpect, one to the other; and ſo in our Example though 5, 6, 7, *&c.* hours lie upon the North-Eaſt part of the Horizon upon the Morning, yet by them you are to underſtand the ſame hours of 5, 6, 7, *&c.* on the South-Weſt part of the Heavens on the Evening tide.

SECT.

SECT. IV. *To find what Number of Degrees each Hour beareth from* 12, *upon the Limb or Horizon of the Inſtrument.*

THis is eaſie to be done, for in a Projection for *London*; you ſhall find 11 and 1, to be diſtant from 12 at Noon, 11 deg. 51 min. 10 and 2 are diſtant 24 deg. 19 min. 9 and 3, 38 deg. 3 min. 8 and 4, 53 deg. 35 min. 7 and 5, 61 deg. 6 min. 6 and 6 are diſtant 90 degrees. So likewiſe, you may find 5 in the Morning, and 7 at Night, to be diſtant upon the Horizon from the South 108 deg. 54 min. and 4 in the Morning with 8 in the Evening to be diſtant 126 deg. 25 min. the uſe of this Propoſition will appear in the next Chapter.

SECT. V. *To find upon the Planiſphere,* 1. *The Parallel of the* 12 *Signs.* 2. *The Parallel for every length of the Day.* 3. *The Parallel of every known Declination.*

1. FOr the firſt, which are the Parallels of the beginnings, or any other part of every Sign, the Inſtrument it ſelf will ſhew readily, becauſe there are the Characters of the Signs annexed to them, and theſe Parallels are ſo framed that they anſwer to each degree of the Ecliptick, as in the ſtructure of the Inſtrument is declared, and in this Chapter, Propoſition the firſt.

2. For the Parallels noting out the juſt length of day, look into the Arch and Chord mentioned *Chap.* 1. *Sect.* 7. for thoſe two Lines will help you in this fully after this manner. Let the day be 14 hours long, take $\frac{1}{2}$ that length, *viz.* 7, that ſhews the time of Sun-ſetting; to this time reckoned in the ſame Chord now mentioned apply your Ruler, ſo ſhall it ſhew you upon the Arch, the place in which the Sun is at that time when the day is 14 hours long, which is ♉ or ♌, 29 at *London*. If then according to Propoſition 1. in this Chapter, you look for that degree of *Taurus* 1, or *Leo* 29, amongſt the Parallels there may you affirm the Parallel for that length of the day to paſs along, ſo if the length of the day had been 10$\frac{1}{2}$ hours, half that length 5$\frac{1}{4}$ ſhews the time of Sun-ſet. If therefore you look upon the Chord of 5 hours 15 minutes of an hour, which is as much as 3$\frac{3}{4}$ deg. and thereto apply the Ruler, you ſhall find it to cut upon the Arch of ♎ 22 or ♓ 8 degrees, which are the degrees of the Ecliptick wherein the Sun being makes the day of 10 hours and 30 min. length.

3. The manner to find the Parallel upon your Inſtrument anſwering to any known Declination, may be ſeen by an Example. Suppoſe the Declination from the Equinoctial to be 15$\frac{1}{6}$ deg. Northward, count that Declination upon the Limb of your Inſtrument from N towards W, and thereto lay the Ruler, which will alſo immediately ſhew you upon the Arch the Sun's place to be ♉ 11 or ♌ 19. And if the ſame Declination had been Southerly, then muſt you have counted it on the Limb from N towards E, and the Ruler there laid ſhews upon the Arch the degrees of the Ecliptick anſwerable, to be ♏ 11, ♒ 19, if then according to the firſt Propoſition, you look for the Parallels of thoſe degrees in that Inſtrument, they ſhall be the Parallels of the fore-named Declinations.

SECT. VI. *The Interſection of any Hour-circle with any Parallel being aſſigned, to find what Altitude the ſame ſhall have above the Horizon.*

THis is uſeful for many purpoſes, (as hereafter is ſhewed) and moſt eaſie to be performed; For having your Parallel given, you by the laſt Propoſition, ſhall ſee quickly where every Hour-circle cuts through the ſame; unto thoſe Interſections apply your Ruler, ſo ſhall the degrees of the ſame Ruler, being counted from the Horizon, ſhew you the Altitudes required: So in ♉ 1, or ♌ 29, when the day at *London* is 14 hours long, the Sun's Altitude at 9 or 3 a Clock will be 36 deg. above the Horizon: And in ♌ 19 degrees, the Sun's Altitude at 9 and 3 a Clock, will be 38½ degrees; and ſo of all other Parallels and Hours.

SECT. VII. *The Deſcendant Point of the Ecliptick being aſſign'd, to find, 1. What Point of the Ecliptick is in any Hour-circle, and 2. What Altitude it hath.*

Example; LEt the beginning of *Leo* deſcend at *London*, I would then know what degree of the Ecliptick is in the hour of 3, and in the hour of 10, at that very inſtant: Firſt, I lay the Ruler upon the beginning of ♌ counted in the Arch, where I ſhall find it to cut upon the Chord 7 hours, and 9 degrees, which hours are to be taken for Afternoon hours: Now from 3 a Clock to 7, and 9 degrees Afternoon, are 4 hours, and 9 degrees, which turned into degrees, makes 69 degrees: And ſo from 10 a Clock, to 7 and 9 degrees Afternoon, are 9 hours, and 9 degrees, or 144 degrees: Theſe being fore-known, go to the Triangular Lines, and becauſe the Sign deſcending is ſuppoſed to be ♌, lay your Ruler at ♌ in that Line betwixt N and E, and mark where it cuts the Limb, namely, at 2⅓ degrees from 60 towards 50. Now from hence count upon the Limb *ſecundum ſer. ſignorum*, 69 degrees, your firſt number of degrees, which will fall between N and W upon 11⅓ degrees, whereto again lay your Ruler, which you ſhall find to cut upon the Triangular Line ♎ the 12, almoſt; And this is the degree of the Ecliptick which is in the hour of 3, when the beginning of ♌ is deſcending at *London*; And if you apply the Ruler to ♎ 12, in the hour of 3: the Altitude of it ſhall be 21½. Secondly, lay your Ruler again at ♌ in the Triangular Line, that it may cut 2⅓ degrees, from 60 towards 50, and from the Ruler ſo laid, count 144 degrees, which is the Number for 10 a Clock, ſo ſhall the Number go from N towards W 84⅓, whereto if you apply your Ruler, you ſhall find it to cut about the 25th deg. of ♐, and this is the degree of the Ecliptick that is in the hour of 10, when the beginning of ♌ is deſcending under the Horizon at *London*, and if you apply the Ruler to ♐ 25 deg. in the hour of 10, you ſhall find the Altitude of it 10¼. The like may be done for any other Sign, or degree; And remember that when ♌ is deſcending, then is ♒ the oppoſite Sign aſcending above the Horizon, and what is done for the deſcending of ♌, is likewiſe done for the aſcending of ♒.

SECT.

SECT. VIII. *The Culminant Point of the Ecliptick being assigned, to find at that time; 1. What Point of the Ecliptick is in any Hour-Circle. 2. What Altitude it hath there.*

THe Culminant-Point, is that Point which is in the Meridian at any time. This Work will be somewhat easier than the former, as will best appear by an Example: Suppose at *London* (or any where else, for the first part of the Proposition is general, and therefore a man may make Tables if he list, for this first part of the Proposition, which will serve for all Latitudes) the beginning of *Leo* were Culminant, and I would know what degree of the Ecliptick is in the Hour-Circle of 8 in the Morning: Because from the Meridian to 8 a Clock, is 4 hours, or 60 deg. and that forward *secundum seriem signorum*, therefore first I apply the Ruler to ♌ in the Triangular Lines, where it cuts in the Limb $2\frac{1}{3}$ deg. from 60 towards 50; from thence I count 4 hours or 60 deg. forwards towards N, which will fall in the Limb upon the quarter N, W, or $2\frac{1}{3}$ deg. from N, and then the Ruler shews upon the Triangular Line about ♎ 3 deg. to be in the 8 a Clock hour: Now the Altitude of that Point in that hour, is 17 degrees, as the Ruler applied to it will shew: Again, if the beginning of ♌ be supposed Culminant, and I would know what degree is in the hour of 5 Afternoon at that same time; because from the Meridian to 5 a Clock, are 75 degrees, and that *contra ser. signorum*; therefore having first laid the Ruler upon the beginning of ♌ in the Triangular Lines, which cuts as before, $2\frac{1}{3}$ deg. from 60 towards 50, in the Limb, from whence I count backwards towards E and S, in the Limb 75 deg. which will fall upon $4\frac{1}{3}$ deg. from 50 toward 40 in the South Equator, and the Ruler being laid here will cut upon the Triangular Line on the opposite part of the Instrument about the 19 deg. of ♉, and such is the deg. of the Ecliptick, which possesseth the hour of 5 a Clock Afternoon, when the beginning of ♌ is in the Meridian.

Then for the second thing which is particular to every Latitude, if you apply the Ruler to the 19 deg. of ♉, in the hour of 5, you shall find the Altitude of that Point to be 23 deg. in the Latitude of *London*: The opposite Points are in the opposite hours below the Horizon, at the same time when the beginning of ♌ is in Culmination, or the beginning of the opposite Sign ♒ is in *Imo Cœli*, is as easie to be understood.

What Propositions soever are here done for hours (as what Altitude any thing hath upon Hour-circles,) do the same also upon Azimuths, for there will be need of them hereafter, in putting the Furniture into refracted Water-Dials, &c.

APPENDIX.

The Description of the SEMICIRCLE.

THE Semicircle it self, and the two Squares that are in it, are so commonly known, that I shall not need to say any thing of the Division of either of them, especially since the Figure of it is here ready to represent the same as fully as can be required; only remember that I call M N the Semidiameter of it, and L K the Diameter.

The difficulty that is, is in the contrivance of it. The Limb above the Semicircle noted with I K, must be of such breadth, that if the Thread hang upon the Diameter L K, the Plummet may have liberty enough without touching the Ruler A B at all: upon that breadth also you are to set two Loops as at E and F, through which the Ruler must have just room to slip up and down as occasion shall be: and that it may be fastned from slipping when it is required it should be fixed, you must either make two Scrues at the back-sides of those Loops, or two Wedges, such as are signified by G and H, which Wedges must be so shaped, that though they be loosed, yet they shall not slip out, and to that purpose, at their lesser ends they have little knots left, as the Figure declares. Yet if you draw out the Ruler to turn the other edge of it towards the Semicircle, (as sometimes of force you must) then may the Wedges be taken out if need require; and again, first, put in before the Ruler, that when the Ruler is put in, they may be kept there, and not lost. The Ruler being thin as of Brass, or other Metal, such as this Figure represents, must be sharp at both ends of one of the Edges, as the Picture shews, but if it be of Wood, and so become of more thickness, then must you line the two very ends of the edge of your Ruler with a little plate of Brass like the Figure R O P, laid in strait and even with the end of the Ruler, and at the end of that plate make two sharp points, as O and P do manifest, standing even with the two very edges of the upper flat of the Rule; And so the other end of the Rule must be placed upon the same edge in the same manner.

Let the Ruler be about three times the length of the Diameter of the Semicircle.

Now instead of this Semicircle in narrow places, and where room is wanting, may a Triangle of past-board be used for the elevation, or depression of any thing, the Figure whereof appears with the Semicircle.

The use of the Semicircle is general; As upon a Line drawn any where, to project any Altitude or Depression above or below the Horizon, from a fixed Point that stands at a distance from that Line.

It will be convenient to have 2 or 3 Semicircles of several bignesses.

THE manner is easie: For if you hold the edge of your Ruler to the fixed Point, and also apply the point of that edge to the Line given, removing it higher, or lower, till the Thread hanging down by the side of the Semicircle directed to it, at full liberty, do fall upon the Altitude intended, then doth the Ruler lie at the Altitude or Depth, and project it from the fixed Point

Point into the Line, as is required: You muſt in this Work (as occaſion is) turn the Ruler, and remove your Semicircle, and ſo in other occaſions.

¶ Note, That whereſoever in the following Precepts I mention the Semicircle, a Quadrant ſo fitted with a Ruler, and divided on both ſides, will ſufficiently ſerve the turn.

CHAP. IV.

A general and moſt eaſie way to project Hour-Lines upon all kinds of Superficies without any regard had to their ſtanding, either in reſpect of Declination or Inclination.

LET a Gnomon, being firſt ſharpned into a Point, be ſhaped, and faſtned in ſuch wiſe, that it no way hinder either the draught of the Horizontal Line, or the Point of the ſhadow from having free acceſs to the Dial at all times of the Year.

2. Draw an Horizontal Line, by help of your Semicircle in a true Level both in regard of it ſelf, and alſo to the Point of the Gnomon, through the whole Superficies on which the Dial is to be deſcribed. Or having two Points in the ſame Level with the Point of the Gnomon, project it upon your Superficies, if it be a rugged one. And if the Superficies be more than one, or if any of them be very much inclined toward the Horizon, or elſe be very rugged, or far remote from the Gnomon, ſo that it will not at all, or not ſo well, receive an Horizontal Line upon it, you may *Either* ſet up ſome Board, or ſuch like Object, upon which for a time you are to inſcribe the Horizontal Line, and by help of which the Hours are to be projected upon the Superficies; *Or* elſe (which perhaps will be better) you may extend a Thread in the Air (it matters not which way, nor whether from the Gnomon towards the Sun, or from the Sun: whether ſtretcht out in one length, or with returns, ſo long as it lieth juſtly parallel, in every Point of it, to the Horizon, and in the ſame Level with the Point of the Gnomon:) which being fixed in this manner, will very well ſupply the uſe of the Horizontal Line: or the Horizontal Line may be partly Thread, and partly drawn upon the Superficies, as occaſion ſhall be. And upon it may any Point be transferred, and ſigned out by ſlipping knots of Thred tied upon it.

3. Upon the Superficies of the Dial, obſerve the Point of the Shadow of the Gnomon (making a mark at it) and the Sun's Altitude, both of them at the ſame inſtant of time.

4. By the Altitude obſerved, compute the Azimuth of the Sun from the Meridian.

5. The ſame Azimuth muſt be transferred unto, or projected upon, the Horizontal Line by help of a Perpendicular Thread, covering to your ſight (as it hangeth down) the Points of the Gnomon and Shadow both together; and at the ſame view cutting through the Horizontal Line: obſerve then punctually where it cuts through the ſame Line, for that ſame Section being ſigned thereon, ſhall be the Azimuth projected into the Horizontal Line.

6. Let any kind of board or paſt-board be now applied to the Point of the Gnomon; ſo, as that it may be ſtaid, either upon the Horizontal Line (where it

it may ſo be conveniently) or at leaſt ſo placed toward the Horizontal Line, that it may have a juſt reſpect unto it, and in that poſture may have ſome ſtay for the edge of it to reſt upon, that after it is furniſhed with ſuch neceſſary Lines as muſt be drawn upon it, it may be placed in its former juſt poſture without any Impeachment. Upon this Plain ſo placed, let the Point of the Gnomon be ſigned, which may be called the Center; and from this Center, to the Sign of the Azimuth, before projected into the Horizontal Line, draw a right Line: this right Line ſo drawn, ſhall repreſent upon the board or paſt-board, the ſame Azimuth which was before computed.

7. Then taking away the ſame Plain, draw upon it the Meridian or Line of 12; extending it from the Center before noted, at the true Angle that it hath from the Azimuth before computed and deſcribed, and alſo toward the true Coaſt of the World. And let it be extended on both ſides the Center if need be.

8. To the Meridian ſo pitched upon the paſt-board, draw (from the Center) the Lines of an Horizontal Dial made to that Latitude wherein you are.

9. Then again, let the plain board or paſt-board be applied to its former ſituation, the Center of the Horizontal Dial reſting upon the Point of the Gnomon, and every thing elſe anſwering to the ſame juſt poſture that it had at the firſt. Which done, let a Thread be fixed in the Center of the Horizontal Dial, by help whereof you may transfer every hour from the paſt-board into the Horizontal Line. Let every hour be therein noted (by fixing marks upon the Horizontal Line where it is drawn, or by ſlipping knots ſet upon the Thread, where a Thread Horizontal Line is uſed) eſpecially mark out the hour of 12: For which (if it chance to run beſides the Superficies) ſome kind of Object (whereon the Horizontal Line is alſo to be drawn) or an Horizontal Thread muſt be faſtned, that may receive it, till ſuch time as your Dial be finiſhed.

10. After all this, take your Plain away (for there will now be no more need of it) and conjecture whereabout the Axis of the World, would paſs from the Point of the Gnomon to the Poles of the World, for into that place is the Meridian to be projected. Which that it may be done more commodiouſly, if no object ſtand in the way that will receive it, you muſt place one there, it matters not whether above or below the Gnomon, chuſe that which is moſt convenient: Or, a Thread laid aſlope in the Meridian juſtly as it ought, will ſerve as well as may be. If then you hold up a perpendicular Thread, ſo that by your eye you may ſee the Point of the Gnomon, and alſo the Point of 12 in the Horizontal Line, both together, the ſame Thread ſo hanging, ſhall ſhew where the Meridian is to be drawn. Or, you may extend a Thread from the Point of the Gnomon to the Point of 12 in the Horizontal Line, which Thread ſhall repreſent the Line of 12: And ſtaying your Thread there, cloſe to it, hang up two perpendicular Threads at a good diſtance, ſo ſhall the ſame two Threads, give you the track of the Meridian Line.

11. The next Work will be to project one of the Poles of the World (that namely, which lies the ſame way that this projected Meridian doth from the Point of the Gnomon) into this Meridian. And this is done by elevating or depreſſing your Semicircle, from the Point of the Gnomon towards the Meridian Line, according to the Latitude of your Place; for ſo will the Ruler of the Semicircle, or a Thread extended along by it, Sign out the very Pole Point. If now you extend a Thread from this Pole Point, to the Point of the Gnomon, the ſame ſhall repreſent the Axis of the World.

12. Laſt of all; by theſe helps, all the hours may eaſily be projected. For

if

if the eye do lay, or project, this Thread or Axis upon each Point of those hours that were inserted before into the Horizontal Line, the Axis upon an hour Point, or a Point upon the Axis, each one of those Projections shall represent upon your Dial, each of the hours required, and will shew upon every Object that stands in the way, where the hours are to be drawn. Or, where convenient room is wanting to place the eye, so as it may make this Projection; there may 2 Threads be used for the same purpose, one whereof must be fastned to the Point of the Gnomon, the other to the Pole designed in the Meridian Line. Then stretching one of the Threads to any of the Points noted in the Horizontal Line, and holding it there, you may take the other, and extend it to the Superficies, so as it may closely pass by the first Thread, by which Work you may make as many Points upon your Superficies as you please, through which each hour is to be drawn. Having thus traced the way before hand, you may afterward draw the hours without any difficulty, be the Superficies never so irregular. Among which Lines, the Shadow of the Point of the Gnomon, as it creepeth along, will shew the Time of the Day.

CHAP. V.

Let this stand as a briefer and less troublesome way, than the former: The Problem may be propounded more generally than before, in this manner.

IF a Point be assigned upon any Superficies Flat or Curved, one, or more, wherein the Hour-Lines and Axis shall concur, how to project the Hours to that Point, and to set up an Axis after the ordinary manner to give Shadow to them without any knowledge how the Dial standeth, in respect either of Declination or Inclination.

1. To the Point assigned (upon any side of it) by direction of your Semicircle or other Level, stretch out an Horizontal Thread, serving for the Horizontal Line; this Horizontal Line need not be one direct Line, but may be turned at one or more Angles, provided that it lie totally in the Superficies of the Horizon.

2. With a perpendicular Thread held up, project the Sun into the assigned Point, and into the Horizontal Thread, and tie a little mark of Thread upon the same Horizontal, through which the Shadow cutteth. At the same instant also, take the Sun's Altitude.

3. By the Altitude taken, find out the Azimuth; This Azimuth, what ever it be, is represented by the knot.

4. Apply a past-board to the assigned Point, and hold it flat that it may answer to the Horizontal Thread also, and upon this past-board protract your Azimuth by a Thread extended from the Point assigned for the Center, to the mark upon the Horizontal Thread. This done,

5. By help of that Azimuth upon your past-board, protract the Meridian Line, observing the true Coast, and quantity of the Angle from the Azimuth: and to the Meridian describe an Horizontal Dial.

6. Applying the past-board to its place again, all things standing right as before, project all the hours into the Horizontal Thread from off the past-board, and set marks upon the same for the points of each several hour which marks may be little moveable knots to slip to and fro upon the same Thread.

7. Project the Meridian Point by a perpendicular Thread upon some object into that place whereabouts you imagine the Axis of the World would pass, above or below from the Point assigned for the Center.

8. With your Semicircle elevated or depressed (as it shall be required) from the Point assigned for the Center, according to your Latitude project the Pole of the World.

9. Extend a Thread from the Point assigned for the Center to the Poles of the World, which shall represent the Axis.

10. By the Point upon the Horizontal Thread, and this Axis (either by your eye, laying the Axis to the hour-points, or laying the hour-knots to the Axis) you may project all the hours and draw them; Or else you may let the Axis alone, and content your self with the Pole-point projected into the Meridian, for if from the point assigned to be the Center or meeting of the hours and Axis, you extend a Thread to each hour-point in the Horizontal Line, and do repose (with your eye) the same Thread upon the Pole-point, then shall the Shadow of the Thread give you that hour-line, and so do in all the rest.

11. Your Thread or Axis lying in its true situation, you may easily fit an Axis to the same posture. If your Dial be described upon a plain Superficies, you may then (by one side of a Nominal Square, applied to a Thread or Axis, and the other side lying upon the plain) find out the substile, and measure from it the elevation of the Axis above the plain: But if the Dial be described upon a curved Superficies, you must be content to set up your Axis by the direction of the Thread only.

12. This point assigned for the Center being a point of the Axis, is as it were the Apex of the Gnomon, unto which all the Work is projected. But if it be required to set up an Axis to such a Superficies, upon which the Axis and hours will not meet in any tolerable manner, because perhaps the Axis may be but of very small elevation above the Superficies, and yet an Axis is required: in this case, set up any point (of Wire, or such like) of such distance from the Superficies, as that the Axis and hours may be distinct: And through that point let it be required to make the Axis pass, you have no more to do but only to project to this point, as before, by letting the Shadow of a perpendicular Thread pass through that point, and noting the same upon your Horizontal Thread and counting that end of the Wire as your Center, proceed as before, for the Thread that lies to project the hours is a pattern for the Axis.

This way is as general as the former, serving to project the hours upon many Superficies, be they plain or curved, and however situate whether contiguous, or separate, and that without any laborious inquisition of any of their Situations, in respect of Inclination or Declination. If you will put in that Furniture which is usual, you must make some mark (notch, or button) upon your Axis, unto which (as representing the Center of the World) by help of your Semicircle you are to project the Altitudes of such greater or lesser Circles as you intend to insert; As hereafter shall be taught.

The 12 Propositions in the first way were to project to an Apex.

These 12 Propositions answerable in the second way are to project to an Axis.

CHAP.

CHAP. VI.

Being a Third Way, of drawing Hours upon all Plains whatſoever, by the joynt Uſe of the Semicircle and Horizontal Projection or Planiſphere, without knowing their Situation at all.

(I.) *To draw the Hour-Lines upon any Plain.*

(II.) *To project Hour-Lines upon any Superficies, not Plain.*

1. SHape your Gnomon into ſuch a Form, and ſet it in ſuch order, as that the Shadow of the Apex may not be hindered from coming clear to any of the hours at all times of the Year, and to the Apex of it draw an Horizontal Line, by the help of your Semicircle, which is inſtead of a Level.

2. At any time (except betwixt 10, and 2 a Clock) obſerve the point of the Shadow, and make a mark at it; and ſo again, when the Shadow is gone a good diſtance forward, make a ſecond obſervation of the end of it, and mark it alſo: Theſe Obſervations are not neceſſary to be made upon the ſame day, but may be done at leiſure, only it muſt be remembred upon what days they were made; And more Obſervations may be made, but not fewer.

3. Theſe 2 Points thus noted are to be taken; Firſt, as 2 Azimuthal Points; and therefore the Azimuths whereto they belong muſt be projected upon the Plain in this manner. Hold a perpendicular (Thread, or what elſe) to the Apex of the Gnomon, and then (keeping your eye at a good diſtance from the Thread that the Work may be the more exact) remove your eye until you ſee your firſt mark upon the Plain; or hold a perpendicular any where, and move both it and your eye till you can ſee the Thread to cut both the Apex of the Gnomon, and the Point upon the Plain, then mark ſome other Point under the appearance of the Thread upon the Plain; ſo a ſtrait Line drawn upon the Plain from theſe two Points ſhall be that Azimuth-Line, wherein the ſhadow of the Apex was firſt obſerved, and it muſt be drawn over the Plain blindly, as far as conveniently it may both upwards and downwards: in the ſame manner muſt the ſecond Azimuth be projected and drawn through the ſecond point of obſervation: And becauſe theſe Lines ſhould not go further from the Gnomon than the length of the Ruler of your Semicircle will reach, and yet if you ſhould work all upon the Plain, longer Lines ſhould be required, you may therefore (to help forward your Work) affix two little boards edgewiſe upon your Plain, which may receive the aforeſaid Azimuths projected upon them by the Thread held as before, all under one Work.

You may beſt ſet up two Threads, which may appear in perpendicular, either before, or behind the Gnomon's Point; either upright, or aſlope, provided only that they appear in perpendicular.

If a moveable Gnomon of light be made of one upright piece of wood, or ſtone in a window, then may the hours be drawn thereto by this Planiſphere and Semicircle.

4. Theſe two Points are again to be conſidered as the Points of two Almicanthers, to which, that you may know what they are, apply one point of the Ruler of the Semicircle to the firſt of them, and the edge of the Ruler to the Apex of the Gnomon, the Semicircle it ſelf in the mean time hanging down right with his Thread and Plummet at full liberty; ſo ſhall the Thread amongſt

mongst the degrees of the Semicircle ſhew you what Almicanther, or Altitude the Sun was in at that time, of the firſt obſervation; the like muſt be done for the ſecond; and if you have need hereafter of more Azimuths, you may make more Obſervations.

5. The next work will be to inſert points into the Azimuthal Lines, through which to draw hours: And for this purpoſe you muſt have recourſe to your Horizontal Projection, and lay the Ruler thereof to the Situation anſwering to your two Azimuthal Lines, as is ſhewed in the remembrance *Chap.* 3. *Propoſition* 2. and the Ruler ſo laid is an Azimuth, the ſame with your firſt Azimuthal Line drawn upon the Plain; wherefore if the Altitudes and Profundities of every hour upon that Azimuth, or Ruler ſo laid be noted, as is ſhewed in the Third Propoſition, *Chap.* 3. and accordingly by the Semicircle be inſerted into the firſt Azimuthal Line, below and above that Horizontal Line, you ſhall have the points of 12 hours, which may be for the preſent blindly figured, that you may only know them again. The manner how to inſert them is by keeping the edge of the Ruler of your Semicircle to the Apex, and the foot of it to the Azimuthal Line, where ever it be, either plain or board, *&c.* ſtill moving it therein higher or lower, till upon the Semicircle, and Plummet hanging right down, the Thread ſheweth the Altitude requir'd. The Altitudes are to be ſet below the Horizontal Line, and the Profundities above. In the ſame manner you muſt count the ſecond Altitude upon the Ruler, and apply it to the proper Parallel of the day when your ſecond obſervation was made, and ſo again place your Azimuthal Ruler upon the Planiſphere in its due Situation anſwering to the ſecond Azimuthal Line upon your Plane; and upon it ſo laid, having ſeen what Altitudes and Profundities each of the 12 hours have, you muſt expreſs the ſame Altitude and Profundity upon your ſecond Azimuthal Line, in like manner as you did before upon the firſt, and if you have any more, you may do the like upon them, though two will ſerve turn.

6. Such Points then as fall upon the Plain will give you where to draw the hours, if like be joined with like; as if you draw a right Line from the point of 4 in the firſt Azimuthal Line to the like point of 4 in the ſecond, that ſame ſhall be the Line of 4, and ſo of all the reſt, both whoſe Points fall upon the Plain it ſelf. * But for the reſt you muſt by a Thread project them with your eye in this manner: Faſten a Thread to the Apex of your Gnomon, and ſtretch it with one hand from thence to any point on the Azimuth neareſt to you; (Or, contrariwiſe, if it ſhall be convenient faſten it at the hour-point upon the Azimuth, and ſtretch it to the Apex of the Gnomon, and beyond if need be) then holding the Thread ſtill, turn your eye, till it repoſe the Thread upon the anſwerable Hour-point upon the other Azimuth; ſo ſhall the Thread give to your eye the tract of the hour to be drawn upon the Plain. And in this manner you may draw all the hours except 12, for that hour-point falleth always into the very Zenith and Nadir point, where the two Azimuthal Lines concur, which are directly under and above the Apex of the Gnomon, ſo that you have not two diſtinct points to draw it through, as you have for the reſt of the hours, for that therefore we muſt have ſome peculiar way which may firſt be this.

** This Projection may be uſed for all Superficies, as well as Flats.*

1. Having cleared your Plain of all neceſſary ſuperfluity of Boards, Lines, and Figures, *&c.* Obſerve where 6 a Clock cuts the Horizontal Line, for if upon a paſt-board applied to the Horizontal Line you draw a Line from that Section, to the Apex of the Gnomon, and from the ſame Apex draw another upon the paſt-board perpendicular to the former, extending it till it cut the Horizontal Line, the point where it cuts is the point through which 12 muſt

paſs,

paſs, if then you hold a perpendicular Thread till through it you ſee the Apex of the Gnomon, and that point together, the appearance, or ſhadow of the Thread upon the Plain is the Line of 12 required.

2. Another way may be by chooſing any other hour, as well as 6: for if you obſerve upon the Horizon or Limb of the Projection, what degrees lie betwixt it (ſuppoſe 9, and 12) you may apply a paſt-board as before to the Horizontal Line, and from the Section of 9 thereon, to the Apex draw a Line, and upon the paſt-board out of the Apex as a Center delineate that Angle, and draw a Line for it, ſo ſhall that Line be the hour of 12 upon the paſt-board, and ſhew upon the Horizontal Line where 12 ſhould be, which may be projected again as before.

3. Another way will be if you'll prolong any one of your Hour-lines (but the farther from 6 the better, for 6 is altogether unfit for this Work) that way which from the Apex of the Gnomon, you ſhall conceive to go toward the Axis of the World (which your own knowledge of the Heavens will direct you in) there the Ruler of your Semicircle being kept at the Apex of the Gnomon, the point of it may be removed upon the hour till ſuch time as the Plummet hangs at your Latitude, and the Ruler then will lie in the Axis of the World, and at the foot of your Ruler ſo placed in that Hour-line make a Point. This Point is that which in other ways of Dialling, is the Center of the Dial, to this therefore the hour of 12 muſt come; If then you by a perpendicular Thread, will ſee the Apex of your Gnomon and this Point together, the ſame Thread ſhall upon the Plain, ſhew you alſo the place where 12 muſt be drawn. And note that from the points upon one Azimuth to this point (found by the third way) you might draw or project all the former hours, or moſt of them, in ſuch ſort as is ſhewed before. And further be ever mindful that you draw all the Hour-lines (in what place of the Plain ſoever they happen to be) down that way that they may come under the Horizontal Line, by ſufficient extending them thither; for otherwiſe they will not be of any uſe: ſince the ſhadow of the Apex is always under, never above the Horizontal Line.

Theſe Precepts though they are here ſet down as for plainneſs only, yet the ingenious will eaſily find how to apply them to any curved Superficies; only the Work in them will be a great deal more, and of more trouble; but theſe will be better done by my laſt way, which is more ſimple and general than this: yet notwithſtanding for the Furniture of Dials, both here and in my laſt, I intend to make uſe of this way by the Horizontal Planiſphere, which is the eaſieſt that ever was. And when I mention the Horizontal Planiſphere: I would not have the Reader think, that theſe things can be done by no other Inſtrument; for the Mathematical Jewel of Mr. *Blagrave*'s firſt contrivance, ſince amplified by Mr. *John Palmer* Rector of *Ecton* in *Northamptonſhire*, will do all theſe things to all Latitudes, whereas this will do them but for Dials in one Latitude; and otherways I can do, and ſo I doubt not but others will alſo find; but I would have him know this withal, that no one Projection is ſo eaſie for this Work, as this, and therefore I made choice of it, and have fitted it with ſuch Lines as I could yet find to be moſt uſeful for the purpoſe intended. I proceed therefore to ſhew how by it and the Semicircle, all that other men have written on this Subject may moſt eaſily be performed.

Note, *Th[e] Analemma f[or] this Work is th[e] moſt Univer[-] ſal, and abſolu[te] Inſtrument for theſe performances of which I may take occaſion t[o] treat hereafte[r].*

CHAP. VII.

Upon a Plain (but not upon a curved Superficies) to make a Dial with an Axis, to any Point assigned for the Center.

FIRST, project a Dial to the Point of a Gnomon, the projective way; then having assigned your Center, from it, draw hours parallel to the projective ones, so are you furnished with hours. For the Axis do thus:

Note, That it must pass through the Center of the Dial, and must be parallel to that Axis that was drawn from the Point of the Gnomon.

Now to set it absolutely parallel, it must be remembred, that when the Gnomonical Axis is reposed upon the Center of this new drawn Dial, it must also cover the new Axis, that is, to your sight, must lie just under it, and being limited to that Superficies you may the more easily stretch a Thread from the Center, parallel to the Gnomonical Axis: Or use your Semicircle being elevated to your Latitude, and kept in the fore-named Superficies.

CHAP. VIII.

How to Project Hours upon a Glass-Window, where the Hours shall be drawn within, the Gnomon standing without where you cannot come at it.

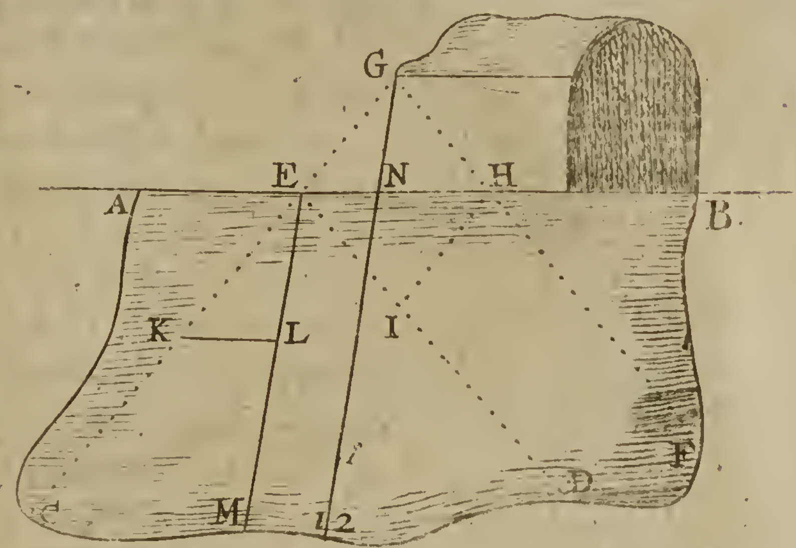
1. FIX your Gnomon on the out-side of the Window, and observe the point of the Shadow that it makes upon the Glass, making a mark at it, and take the Sun's Altitude at the same instant, whereby the Sun's Azimuth at that moment may be discovered.

2. By help of a Quadrant, Semicircle, or Level, draw an Horizontal Line upon the Glass, true to the Point of the Gnomon. This may be done if you hold the upper side of your Quadrant or Instrument truly level with the Horizon (which the Thread falling upon the perpendicular Line will direct you to do) and the Instrument being kept so levelled, must be fitted up higher or put lower, till such time as your eye viewing along the forenamed level-edge can discern the Point of your Gnomon. Observe at that time and in that posture, where the Point of the Gnomon appears upon the Glass, and make a mark at it, and so do the second time, and make a second mark; through these two marks a Line drawn will be an Horizontal Line upon the Glass, lying level with the Point of the Gnomon.

3. By a perpendicular Thread directed to the mark of the Azimuth, and to the point of the Gnomon both together, the same Azimuth must be projected into the Horizontal Line upon the Glass, with the Section of the Horizontal Line, and the Thread appearing upon the Glass will determine for you.

4. From

4. From this Azimuth muſt a Meridian Line be found out, wherein will be a little trouble, the way that I go about it is this. Apply a paſt-bord, as A B C D. to the Horizontal Line upon the Glaſs which is A B. upon the paſt-board being held truly Horizontal Project with a perpendicular Thread the Azimuthal Point E which was before inſerted into the Horizontal Line A B. and let the Line projected be C E. Then again (towards that Coaſt whereunto your Meridian Line ſtandeth) with a perpendicular Thread, project upon the ſame paſt-board (held Horizontal, and in the ſame place as before) any other Azimuth at adventure, as F G. cutting through the Point of the Gnomon at G. and through the Horizontal Line at H. To F H. draw E D Parallel, and from E C. which is your Azimuth before found, ſet off E M. for the Meridian, according to the true Coaſt and Angle. Next of all, you are to draw a Meridian Line parallel to E m, which may paſs through the point of the Gnomon, all which to effect there are many ways, amongſt them I will give this one. From H draw H I parallel to E C. cutting E D at I. then alſo make E K upon E C equal to H I. and from K draw K L parallel to A B. the Horizontal Line cutting E M, in L; And to K L make E N. upon the Horizontal Line equal; ſo ſhall N. be the point of 12 upon the Horizontal Line, whereon it muſt be inſcribed, and N 12, being drawn parallel to E M. ſhall be the Meridian or Line of 12, upon the paſt-board (if there were any uſe of it there) fully reſpecting the point of the Gnomon at G.



Or if you deſire to ſave all this labour of theſe 4 precedent Sections, obſerve upon ſome other Dial, or by ſome Meridian Line before found, when the Sun comes to the Meridian; and at the ſame inſtant make a mark upon the Glaſs at the point of the Gnomon's ſhadow, ſo ſhall that mark be one point of the Meridian or 12 a Clock line. But this ſerves only for ſuch Windows as look upon the South; for North-Windows therefore, the former way muſt of neceſſity be uſed.

5. Having found one point of 12 by one of theſe ways, you are next to project the Meridian Line upon the Glaſs, which becauſe it is alſo an Azimuth, as well as a Meridian may be projected by help of a perpendicular Thread ſo held until the eye ſhew it at once to fall both upon the mark of the Meridian noted before upon the Glaſs; and alſo upon the point of the Gnomon; the ſhadow then of this Thread ſo held ſhall ſhew upon the Glaſs where the Meridian is to be drawn. Remember alſo to draw it both ways, that is above and below the point of the Gnomon.

6. Into this Meridian you are next to project the point through which the Axis of the World would paſs, which if you were without the Window, and could come at the point of the Gnomon, might be done as in the other Dials by the Semicircle; But becauſe you are within, and the Gnomon without, you muſt help your ſelf ſome other way, as thus. Hold your Semicircle or Qua-

drant,

drant, so as that the side which must find the forenamed point may be elevated according to the height of the Pole, and being continually so kept at that elevation and directed also to the point of the Gnomon, lift up or depress the Instrument, keeping one end of it always in the Meridian Line, until your eye viewing along that side that is so elevated shall direct the same upon the point of the Gnomon, and then diligently mark in what part of the Meridian Line it resteth, for that point is the point required.

7. To this point (which is a point of the Axis passing through the Gnomon's point, for to any point of that Axis the hours being described, the Gnomon will shew true) stretch a Thread Horizontal Line level with it, and into this Thread Horizontal Line, by help of a perpendicular Thread project your Meridian before found, that is, repose this perpendicular Thread being duly held, upon the Meridian and point of the Gnomon both together, and at the same time observe where it seems to cut the Horizontal Thread, at the apparent intersection fasten a knot for the point of 12. You may also at the same time and view (all under one) project the Meridian upon some object standing there where about you suppose the Axis of the World would pass, for the appearance or shadow of the Thread shews that also at the same view.

8. To that point upon the Glass as a Center, apply a past-board, upon which from that Center to the Point of 12 draw the Line of 12. and to this Center and Line of 12. draw an Horizontal Dial upon the past-board, and applying the past-board to its former due place, project the hours from the same into the Horizontal Thread, and fasten knots of Thread as marks of every hour.

9. Project the Meridian upon the top or bottom of the Room, or upon some object placed in the way whereabout you imagine the Axis of the World would pass, as is declared in the seventh Section going before. And with your Semicircle elevated or depressed according to your Latitude, project the Pole of the World from the forenamed Center, or Point of the Glass into the Meridian now last of all fitted to receive it, and stretch a Thread from the one to the other, which may represent the Axis of the World.

10. By this Axis and the points of the hours upon the Horizontal Thread, you may easily project the Hour-lines upon the Glass, and accordingly draw them, and so finish up your Dial.

Another Way to draw the Hour-Lines, may be thus:

Having drawn what is prescribed in the Fourth Section, you may piece out your past-board A B C D: (or transfer all the Lines upon it, to a larger paper where more room is) that it may contain the exteriour part of the Draught E G N H; This exteriour Draught you may therefore some ways supply, and to G being the Center, & G N the Meridian, you may draw an Horizontal Dial, and project the hours upon A B, the Horizontal Line of the Glass or past-board. Now then if you apply your past-board so furnished with these Horizontal Points, to its first Situation which it had, and transfer the same Points to A B the Horizontal Line drawn upon the Glass, then may you upon a flat Glass-window through those Points draw strait Lines from the Point of the Axis found by the Sixth Section: which Lines shall be the same hours with them which were drawn the other way. Or, if the Glass-window be not flat, then you may by the 3 Points given (*viz.* the Point of the Axis, the Point of the Gnomon, and the Hour-points on the Horizontal Line) and a Thread, project the Lines on a curved Glass Superficies. Remember that the Point mentioned

tioned in the Sixth Section, ſtands above the Horizontal Line, if the Window look Southward, and below if the Window look Northward.

CHAP. IX.

How to delineate the Hours upon any Superficies, without that way by the Semicircle of elevating an Axis; by obſerving both the Hour and Azimuth at one Altitude taken.

(1.) FIx a Gnomon. (2.) Obſerve the Sun's Altitude, and make a mark of the ſhadow of the Gnomon's point both at one moment. (3.) By the Altitude conclude the Azimuth, and the hour or part of it. (4.) Project the Azimuth into the Horizontal Line. (5.) By that Azimuth protract an Horizontal Dial upon paſt-board, and amongſt the reſt that hour or part of an hour that was obſerved [which muſt be therefore calculated what Angle it maketh with the Meridian upon the Horizontal Plain thus. As the *Radius* to the Sine of the Latitude: ſo the Tangent of that hour or part, to the Tangent of the Space or Angle required.] And project the Meridian, and all the Hour-points from the paſt-board into the Horizontal Line. (6.) Having now the Meridian Point (by a perpendicular Thread) project the Meridian Line, or Line of 12, and draw (upon a Plain or Project upon a rugged Superficies) that hour or part occultly that it may be put out, of which you have two points given, one by Obſervation, the other by Impoſition into the Horizontal Line. (7.) By theſe two Hour-lines, this laſt and the Meridian find out the Axis with your eye, *ut pag. ſequ. Sect.* 2. (8.) Then by the Axis project all the Hour-lines by the points upon the Horizontal Line, *&c.*

2. Or, without obſerving the hour, but uſing the Semicircle do thus, keeping the work for the moſt part as is above declared, enquire what Altitude ſome one hour in the Horizontal Line hath upon that Azimuth; And firſt, having drawn the Azimuth Line projected upon the Superficies, expreſs by the Semicircle the Altitude found, upon the Azimuth drawn: So having two points for one hour; one in the Azimuth, the other in the Horizontal Line, project the ſame hour by the Semicircle, and draw it, as alſo the Meridian. By theſe two hours make an Axis, *&c.* as before: Or as here followeth.

If you will ſtay to obſerve, from ſome other Sun-Dial, the Sun's approach to any one hour juſtly, then make a mark there, you ſhall not need to put in any other hour to be afterwards blotted out, but that which is ſo put in ſhall be a true hour, neither ſhall you need to calculate, as is before required.

Hours being drawn to a Gnomon, how make an Axis.

The Point of the Index is one Point of the Axis, if another Point were known beſides, then might the Axis be drawn, or a Thread placed ſo as the Axis ought to be. To find another Point uſe either of theſe two ways.

1. Faſten one Thread from the Point of the Index to any one Hour-line a good way below the Horizontal Line,and another Thread to another hour that may be 5 or 6 or 7 hours from the former (the more near to 6 hours the better) theſe Threads being held or faſtned as is preſcribed, there muſt be ſtretched out from each of theſe Hour-lines (in ſome other part) to their proper Threads, two Threads more; ſo as that they may only touch (and not force upon) the two firſt faſtned Threads, and theſe two Threads being brought together in that manner till they meet, and cut each other, this Point of Interſection will be another Point where through the Axis is to paſs. If therefore, a Thread be extended from the Point of the Index or Gnomon unto this Point of Interſection,the ſame Thread is the repreſentative Axis of the World, and an Axis of Iron (*&c.*) laid in place of it will give the true ſhadow for the Hour-lines.

2. Or the Axis may be found thus: Faſten a Thread at the Point of the Index or Gnomon,and ſtretch it out with your hand till you ſee it to cover any one Hour-line, there hold it faſt by ſtaying or reſting your hand upon ſome ſuſtentacle; Then try by your eye whether the Thread ſo ſtanding will cover another hour, that is 5 or 6 or 7 *&c.* hours from the former, if it do ſo, and do not make any Angles with it, then is it the true Axis; If it do not ſo, then is it to be removed until it fit in ſuch manner as is declared; ſo may the pattern of the Axis be eaſily ſtretched out by a Thread.

CHAP. X.

How to Project an Hour-line from a Wall upon a Board, which ſtandeth as an hindrance, ſo that you cannot extend any ſtrait Thread from the Point of the Gnomon (or Glaſs) to the ſaid Hour-line at all, becauſe of the ſame Board.

MAke a mark upon the Hour-line in any part of it; Then extend a ſtrait Thread, one of whoſe ends let be faſtned to the foreſaid mark, and the other end at a good diſtance from the Gnomon's Point any where, then repoſe the Thread with your eye upon the Point of the Gnomon, and obſerve the ſhadow, or appearance of the Thread upon the Board, and draw a Line along with it. Again ſtretch your Thread out ſtrait to ſome other place, ſo as you may ſee the Gnomon again under the Thread, and then mark where this ſhadow of this ſecond placed Thread ſeemeth to croſs the former Line drawn upon the Board, there make one mark; then again repeat the ſame Work, that is, make a new mark upon the Hour-line, and faſtning a Thread to it, find out another Point upon the Board in the ſame manner as you did before, ſo ſhall you have a ſecond Point: Through theſe two Points you may draw your Hour-line.

Note, That the Board muſt be ſuppoſed ſo to ſtand, that though you cannot come to ſtretch a ſtrait Thread from the Gnomon Point to any part of the Hour-line, yet you may have room to ſtretch a Thread crookedly over or under, or upon one ſide of the Board.

This Caſe ſuppoſeth a Board to ſtand between the Hour-line and the Gnomon;

mon; but if, in case you were to project the hour from the Board to the Wall that is beyond it, do thus.

Make a mark in the Hour-line upon the Board, and stretch a Thread from the Gnomon to any part of the Wall, at a good distance from the Board, and repose this Thread upon the mark on the Board, then draw the shadow, or line, that the Thread makes upon the Wall, and upon the other side of the Board too, which you may do (if not both together, yet) after that is drawn upon the Wall, for by help of it you may easily draw one upon the other side of the Board: Then again stretch out the Thread to some other place of the Wall, and repose it again upon the fore-named mark, and observe then where it crosseth the former Lines drawn on the Wall, and on the other side of the Board, and make marks at those crosses. Thus again you are to do over the same Work to another second mark made upon the Hour-line, by which means you may draw the same Hour-line upon both Board and Wall, if need be, through these two first and second crosses found upon them. Now if it fall out that upon the Wall you cannot draw a Line though you have two marks, by reason the Wall is not flat, then will the Line (or one part of it) which was drawn upon the side of the Board that looks to the Wall help you to project upon the uneven Wall. For stretching a Thread through the two Points given upon the Wall, and tying another Thread to any Point of the Hour-line drawn upon the face of the Board that looks upon the Wall, you may (by this tied Thread apply'd to the other stretcht Thread) project the hour upon the uneven Wall. So that the Hour-line drawn upon the backside of the Board serves to do that which the Point of the Gnomon (if it could be come to) should do. In the same manner the Wall will help to project the hour upon the Board, if the same should prove uneven.

This Work (at first) did not appear to me any ways useful: For if a right Line cannot be drawn from the Point of the Gnomon to the Wall, how can the Sun-Beams (which is a strait Line) come at it from that Gnomon, and if it come at it what use is it of? At present thinking it of no use (as many Notions of the like kind have sometimes been to me;) Yet this transferring the Hour-line from the Wall to the Board, may sometimes be (and once was to me) of use: For if a Sun-Dial be drawn upon a Board, and it fall out that that Board be taken away, so as that the Sun-Beams thereby be taken off too, then it will be good to transfer the hours from the Board, to the Wall or Superficies standing behind, to save them that they be not utterly lost.

CHAP. XI.

To draw a Dial upon a flat Superficies by means of Three Shadows of a Stile, caused by the Sun upon the same Superficies in one Day, without knowing either the Sun's Declination, the Elevation of the Pole, or Situation of the Plain. fig 1, 2, 3, 4. page 95 Geometrical dialing.

IN the first Figure; Let the Plain be C D F, and the Stile A B, whether perpendicular to the Plain or not, for it sufficeth, to know the Shadows of the extremity B, *viz.* D E F, observed in one and the same Day; that is required by means of those three Shadows, and of the Stile A B, to trace a Dial proper for the place of Observation. *Figure* I.

From

From the Point B, (the extremity or top of the Stile) by help of a Square let fall B C, perpendicular to the Plane, meeting with it in the Point C, (if it happen that the Stile be not perpendicular) then from C, to the Points D E F, draw the Lines C D, C E, C F.

Figure II. Then, (in the second Figure) make a right Line at pleasure 1, 4 equal to C F, and take therein a Line 1, 2 equal to C E, and 1, 3 equal to C D, let the perpendiculars, 2. 5: 3, 6: 4, 7. be raised upon 1, 4, and every one equal to B C, the height of the Stile in the first Figure; then from Point 1, to each of the Points 5, 6, and 7. let right Lines be drawn as 1, 5: 1, 6: 1, 7: making with 1, 4: the Angles, 5, 1, 2: 6, 1, 3: 7, 1, 4: in degrees to the height or Elevation of the Sun above the Horizon at that time of observation of the Shadows, *viz.* the Angle 5, 1, 2, the Shadow being at E; 6, 1, 3, the Shadow being at D; and 7, 1, 4, the Shadow being terminated in F. And from Point 1, as a Center, and at the distance 1, 5: let be described the Arch of a Circle 5, 10, 11, cutting the Lines 1, 6: 1, 7, in the Points 10, 11. from whence let fall Perpendiculars upon 1, 4, which let be 10, 8: 11, 9.

Figure III. Then coming to the third Figure; upon another Plain, as, *a m n o*, let be taken the Point *a*, and by it draw the three Lines *d a o*, *c a n*, and *b a m*, making amongst themselves Angles equal to the Angles made by the Lines C F, C E, C D; in Figure I. each to his own, and on the same side, *viz.* *o a n*, equal to F C E, and *n a m* equal to E C D, as the third Figure sheweth; And these Lines being prolonged on the contrary side, as *o a*, as far as *d*, and making *a d*, equal to 1, 9: which is the distance betwixt 1, and the Point where the Perpendicular falleth which comes from the Point marked in the Line 1, 7. by the Arch of a Circle 5, 10, 11, in *Fig.* II. for as much as 1, 4: represents or resembles C F, (in *Fig.* 1.) and C F, resembles *a o*, in like manner make *a b*, equal to 1, 8: (in *Fig.* 2.) because that 1, 4: (in *Fig.* 2.) resembles C F, (in *Fig.* 1.) and C F, resembles *a o*, (in *Fig.* 3.) in like manner *a b*, equal to 1, 8, (in *Fig.* 2.) because 10, 8, comes or is made of the length, 1, 3: which is equal to C D, (in *Fig.* 1.) and C D, of the same situation or disposition as *a m*, Make for the same reason *a c* equal to 1, 2: and draw the right Lines *c d*, *c b*, as long as shall be needful, and on them in Point *c*, raise *c e*, and *c f*, perpendicular either of them equal to B C, (in *Fig.* 1.) and at the Point *d*, let *d g*, be raised perpendicular to *c d*, and equal to Perpendicular 10, 8: (in *Fig.* 2.) because *a d*, is equal to 1, 8: Likewise on the Point *b*, let be raised the Perpendicular *b h*, (on the Line *c d*) equal to 11, 9: (in *Fig.* 2.) and drawing the Lines *c g i*, *f h k*, cutting *c d*, *c b*, in I and K, and if you draw the Line I K, it will give the disposirion or situation of the Equinoctial Line, respecting or relating to the Lines *o a d*, *n a c*, *m a b*, and making *e l*, Perpendicular to I K, that will represent or shew the disposition or situation of the Meridian-line of the Plain representing or relating to the same Lines *o a d*, *n a c*, *m a b*.

This so prepared make the Angle G C E, (in *Fig.* 1.) equal to the Angle *a c k*, (in *Fig.* 3.) and drawing G C I, that will be the Meridian of the Plain; then make G C, (in *Fig.* 1.) equal to *c l*, (in *Fig.* 3.) and drawing C H, Perpendicular to C I, and equal to the height of the Stile, drawing H G; Let H I, be made Perpendicular to H G, cutting G C, in I, then will the Point I, be the Center of the Dial. Moreover let G O, be drawn at right Angles with or upon G C, which will be Equinoctial; and let G P, be made equal to G H, and from the Point P, as Center, and at the distance P G, describe the Circle G M N, which will represent the Equinoctial.

To

To finish the Dial.

THE Meridian of the place must be found, which will be done if from the Point B, (the extremity, or top of the Stile) a Thread be let fall with a Plummet sharp at the end, until the point thereof touch the Plain, as here in point K, (in *Fig.* 1.) by which from point I, drawing a right Line I K L, that shall be the Meridian of the place. If the Plummet let fall from B, the top of the Stile do not touch the Plain, then put the Butt or end of a Ruler to I, the Center of the Dial, and so as that one of the Arrests or Sides passing by the point B, the top of the Stile, then find a point in the Ruler, from whence a Thread and Plummet let fall may cut or touch the Plain as aforesaid, which will be the Meridian of the place.

And if the Plain be Vertical, that is perpendicular to the Horizon, which is easily known by applying a Thread and Plummet to the Plain, for if it rase and touch the Plain, then is the Plain an upright Plain; And then to find the Meridian, is but to apply the end of the Thread to I, the Center of the Dial, and letting the Plummet hang at liberty, draw a right Line by the Thread, which shall be the Meridian-line of the place. Lastly, Produce I K, the Meridian of the place, till it cut the Equinoctial as in the point L, to which from the point P, let be drawn a right Line P L, cutting the Circle G M N, in M, that Line will represent the Equinoctial, the Line of 12 a Clock of the place for which the Dial is made; Divide therefore the Circle into 24 equal parts, beginning from the point M, and from the point P, by every of those Divisions draw Lines to the Equinoctial, and then from the Center of the Dial I, draw Lines to those Points in the Equinoctial, which will be the Hour-lines for the Dial; to which Hour-lines, give the Number or Denomination according to that of the Lines drawn from P, to the point of the Equinoctial Line by which it passeth, (as for Example) drawing a right Line from P, by N, which is the third Division after M (supposing M, to be on the East) that shall be the Line of Three a Clock which shall cut the Equinoctial in O, drawing I O, that will be the Line of Three a Clock of the Dial, and doing so for the rest, the Dial is finished, in which the Hours shall be shewn by the Shadow of the top of the Stile only.

It is to be observed, that in all Dials the Morning Hours ought to be marked on the West-side, and the Evening Hours on the East.

To explain what was said before about finding the Meridian-line of the Place, by a Ruler, with a Thread and Plummet.

LET in the fourth Figure the Stile be A B, the Center of the Dial D, if then from B, be let fall a Thread and Plummet, the Thread joined to B, happens to fall without the Plain, the Ruler I D, must be applied so as that one Arrest or Side thereof, touch both the Center of the Dial in that Figure D, and the top of the Stile B; then finding a point in the Ruler from whence letting fall the Plummet it meeteth with the Plain, that point shall be the Meridian of the place, and drawing from the Center of the Dial D, by that point a right Line, that right Line shall be the Meridian of the place; But if the point in which the Plummet toucheth the Plain be so near the Center that it is difficult to draw the Line exactly, *Figure* IV.

then do thus. Take a point at pleaſure in the ſide of the Ruler as E, to which apply the Thread with the Plummet hanging at liberty, then taking another Thread, ſtaying one of the Butt ends on the point B, and extending the other towards the Plain in ſuch ſort that it may cut the other Thread that hangs at liberty, in perpendicular; that point of meeting of the two Threads, being the point to which the Thread extended from B, will meet the Plain as H, ſhall be the Meridian, and drawing D H, it is found.

We ſpeak not here of all the Difficulties that may happen in deſcribing a Dial by three Shadows; as when the Center of the Dial is not in the Plain, nor when the Meridian of the place cannot be there, becauſe the ſolution of thoſe Difficulties would require a compleat Gnomoniſt.

It may be obſerved from our conſtruction in the third Figure, that if *b c d*, be in a right Line, then that Line is the Equinoctial of the Plain, and that it is a Polar-plain; And that if the Plain be Vertical, its Meridian-line will be that of Six a Clock of the place, to wit, in the oriental or Eaſt ſide, Six in the Morning; and of Six at Night in the Weſt Face: The height of the Stile is for the Semidiameter of the Equinoctial as B C, in the firſt Figure, but the Hour-lines of the place inſtead of meeting in the point I, the Center, are all Parallels one unto another.

CHAP. XII.

Shewing ſeveral ways whereby to find the Star's *Hour readily, and conſequently the true Hour of the Night by the* Stars.

THere are ſeveral ways by which the *Stars* Horary diſtance from the Meridian (call'd the *Star*'s Hour) may be obtained: As,

I. *By any* Quadrant, *or other Inſtrumental* Dial, *which giveth the Hour of the Day by the* Sun.

I Will Illuſtrate this in the Uſe of Mr. *Gunter*'s *Quadrant*, it being an Inſtrument more frequently known than any other of that kind: For,

If you obſerve the ſame Rules in finding the *Star*'s Hour, as is directed for finding of the Hour of the Day by the *Sun*; that is, by ſetting the Bead to the *Star*'s *Declination*, inſtead of the *Sun*'s *Declination*, and then obſerve the *Star*'s *Altitude* as if it were the *Sun*'s *Altitude*, the Bead ſhall then ſhew among the Hour-lines the *Star*'s Hour, or the *Star*'s *Horary* diſtance from the Meridian.

But here you are to Note, That this way of finding the *Star's* Hour, is peculiar to ſuch *Stars* only as are between the *Tropicks*. Wherefore, another more general way may be this:

II. *By*

II. *By a* Sun-Dial *made under the* Soyl, *and on the* Jaums *of a* Jetty *Window, on the inside of a Room. And such a* Dial *may be made by the Rules deliver'd in the* 4th, 5th, 6th *and* 7th *Chapters of the* Eighth Tractate; *or according to these Directions following.*

HAving made a small round hole in any Quarry of Glass in the Window, and darkned the other part of the same Quarry round about the hole, you must upon the Window-Board draw a Meridian Line, which Line must pass directly under the hole before made, and must be transferred to the Cieling of the same Room, by the help of Perpendicular Threads.

Then from the hole in the Window, to the Meridian Line on the Cieling, extend a String, till (by the help of your Semicircle) it make an Angle equal to the *Latitude* of the place you make the *Dial* in, and where the String (with this condition) so resteth, fix the end of the String in that point of the Cieling, letting the other part of the String hang at liberty.

This done, by help of an *Horizontal Dial*, whose Center (for the present) must be placed in the hole in the Window; the Lines of which *Dial* must also be extended by a Thread fixed in the Center thereof, by which Line extended over each Hour, and the String before fixed in the Cieling, the Hour-lines may be transferred and marked upon, or under the Window-Board; and also upon the *Jaums* and *Cheek Posts* of the said Window, and there numbred by Letters or Figures.

Now such a *Dial* being made, I shall shew

How to find the Hour by the Sun *in the day time, and any* Star's *Hour (or his* Horary *distance from the Meridian) in the Night Season.*

1. *By the* Sun.

THE *Sun* shining through the hole before made in the Window, move the String, whose end is fixed in the Cieling, along the Hour Points which are marked about the Window, until such time that the Spot of Light that cometh through the hole of the Window shineth upon the String, and then see upon what Hour, or part of an Hour the String resteth, for that is the true time of the Day.

2. *By the* Stars.

THis differeth little from the former; for when through the Window you see a known *Star*, and would know his Hour, move the String along the Hour Points as before, till such time as you bring your Eye, the String, the Hole, and the *Star*, all four in one and the same Plain, or right Line; for then will the String rest upon that *Star*'s Hour, or his *Horary* distance from the Meridian.

III. *By*

III. *By a* Dial *made in a Yard or Garden.*

IN ſome convenient open place, erect a Pole perpendicular to the *Horizon*, about 10 or 12 foot high; then provide a Frame of Wood in form of a *Parallellogram*, of what bigneſs you pleaſe, (but the ſides being 2 foot broad, and 3 foot long, is a competent bigneſs) within the *Area* of this Frame make the true Hour-Lines of an Eaſt and Weſt *Dial*; which Hour-Lines may be of reaſonable big Wyre, and upon the edges of the Frame, which ought to be of a competent breadth (as 4 or 5 inches) to draw Lines upon, and to ſet the Numbers of the Hours, the Forenoon Hours on the Eaſt ſide, and the Afternoon Hours on the Weſt ſide, and over the Hour-Line of ſix erect an *Axis* (of a competent length) as if it were a *Sun-Dial*: Which *Dial* being thus prepared, if you ſet it upon the former erected Pole, ſo that the two ends of the Frame may ſtand due North and South, and the *Stile* thereof Parallel to the *Axis* of the World, then is it fit for uſe, either to find the Hour of the Day by the *Sun*, or the *Star*'s Hour in the Night.

1. *By the* Sun.

THis is all one as if it were a *Dial* made againſt a Wall; for the ſhadow of the *Axis* upon the Frame will ſhew the Hour of the Day.

2. *By the* Stars.

WHen you ſee a *Star* you know, and would find that *Star*'s Hour; move your ſelf about the *Dial* Poſt (coming nearer to it, or going farther from it) as occaſion offereth, till you bring your Eye, the *Axis*, and the *Star* in the ſame Plain or right Line, and then mind upon what Hour-Line (or between what two Hour-Lines) is intercepted by that view, for that is that *Star*'s Hour; and by this *Dial* you may at any time know,

What Stars *are upon the Meridian.* For,

IF you go behind the North end of the Frame, and look by the ſide of the Frame, you ſhall ſee what *Stars* are then upon the South part of the Meridian.

And if you go behind the South end of the Frame, and look by the ſide of the Frame you ſhall there ſee what *Stars* are upon the North part of the Meridian.

And thus, the *Star*'s Hour (by any of the forementioned ways) being obtained, the true Hour of the Night may be alſo known, by help of the following *Tables* of the *Sun*'s and *Star*'s right Aſcenſion.

A TABLE

A TABLE *of the Complement of the* Sun's *Right Ascension in Hours and Minutes for every Day in the Year.*

Days.	Jan.		Febru.		March.		April.		May.		June.	
	h.	*m.*	*h.*	*m.*	*h.*	*m.*	*h.*	*m.*	*h.*	*m.*	*h.*	*m.*
1	4	25	2	18	0	33	10	39	8	46	6	41
2	4	21	2	14	0	28	10	35	8	42	6	37
3	4	17	2	10	0	24	10	31	8	38	6	33
4	4	13	2	6	0	21	10	27	8	34	6	29
5	4	9	2	2	0	17	10	24	8	30	6	24
6	4	4	1	58	0	14	10	20	8	26	6	20
7	4	0	1	54	0	10	10	16	8	22	6	16
8	3	56	1	50	0	7	10	13	8	18	6	12
9	3	51	1	46	0	3	10	19	8	14	6	8
10	3	47	1	43	11	59	10	6	8	10	6	4
11	3	43	1	39	11	55	10	2	8	6	6	0
12	3	38	1	35	11	52	9	58	8	2	5	56
13	3	34	1	31	11	48	9	54	7	58	5	52
14	3	30	1	27	11	45	9	50	7	54	5	48
15	3	26	1	24	11	41	9	47	7	50	5	43
16	3	22	1	20	11	37	9	43	7	46	5	39
17	3	18	1	16	11	34	9	39	7	42	5	35
18	3	14	1	12	11	30	9	35	7	38	5	31
19	3	10	1	8	11	27	9	31	7	34	5	27
20	3	6	1	5	11	23	9	28	7	30	5	22
21	3	2	1	1	11	19	9	24	7	26	5	18
22	2	57	0	57	11	16	9	20	7	22	5	14
23	2	53	0	54	11	12	9	16	7	18	5	10
24	2	49	0	50	11	5	9	12	7	14	5	6
25	2	45	0	47	11	8	9	9	7	10	5	2
26	2	41	0	43	11	1	9	5	7	6	4	58
27	2	37	0	39	10	57	9	1	7	2	4	54
28	2	33	0	35	10	54	8	57	6	50	4	50
29	2	29			10	50	8	53	6	54	4	46
30	2	25			10	46	8	50	6	49	4	41
31	2	22			10	43			6	45		

A TABLE *of the Complement of the* Sun's *Right Ascension in Hours and Minutes, for every Day in the Year.*

Days.	July.		August.		Sept.		Octob.		Nov.		Dec.	
	h.	*m.*	*h.*	*m.*	*h.*	*m.*	*h.*	*m.*	*h.*	*m.*	*h.*	*m.*
1	4	37	2	35	0	41	10	50	8	53	6	45
2	4	33	2	31	0	37	10	48	8	49	6	39
3	4	29	2	27	0	34	10	45	8	45	6	35
4	4	25	2	23	0	30	10	41	8	41	6	31
5	4	21	2	20	0	27	10	38	8	37	6	26
6	4	17	2	16	0	23	10	34	8	33	6	22
7	4	13	2	12	0	19	10	30	8	29	6	18
8	4	9	2	9	0	16	10	26	8	24	6	13
9	4	5	2	5	0	12	10	22	8	20	6	9
10	4	1	2	2	0	9	10	19	8	15	6	4
11	3	57	1	58	0	5	10	15	8	11	6	0
12	3	53	1	54	0	1	10	11	8	7	5	55
13	3	49	1	50	11	58	10	7	8	2	5	51
14	3	45	1	46	11	54	10	3	7	58	5	46
15	3	41	1	43	11	51	10	0	7	53	5	41
16	3	37	1	39	11	47	9	56	7	49	5	36
17	3	33	1	35	11	43	9	52	7	45	5	32
18	3	29	1	32	11	40	9	48	7	41	5	27
19	3	25	1	28	11	36	9	44	7	37	5	23
20	3	21	1	25	11	33	9	40	7	32	5	19
21	3	17	1	21	11	29	9	36	7	28	5	15
22	3	13	1	17	11	25	9	32	7	24	5	11
23	3	9	1	14	11	21	9	28	7	20	5	6
24	3	5	1	10	11	18	9	24	7	15	5	2
25	3	2	1	7	11	15	9	21	7	11	4	57
26	2	58	1	3	11	11	9	17	7	7	4	53
27	2	54	0	58	11	7	9	13	7	3	4	49
28	2	50	0	56	11	3	9	9	8	58	4	44
29	2	46	0	52	10	59	9	5	8	54	4	40
30	2	42	0	49	10	56	9	1	8	49	4	35
31	2	39	0	45			8	57			4	30

A Table of the *Right Aſcenſion* of ſome eminent *Fixed Stars*, and by them to find the Hour of the Night, and when they will be upon the Meridian.

The Stars Names.	R. Aſcenſion.		The Stars Names.	R. Aſcenſion.	
	h.	m.		h.	m.
The Southerm. in Whale Tail.	0	27	*North Ballance.*	3	0
Girdle of Andromeda.	0	51	*The Crown.*	3	25
Foremoſt Horn of the Ram.	1	36	Scorpion's *heart.*	4	9
Whale's *Belly.*	1	36	Hercules *right Shoulder.*	4	16
South-Foot of Androm.	1	43	Hercules *Head.*	5	0
Whale's *Jaw.*	2	45	Ophinons *Head.*	5	20
Brighteſt of the Seven Stars.	3	28	Lyra, *The Harp.*	6	22
Bull's Eye, Aldebaron.	4	17	*Vulture's Tail.*	6	51
The Goat, Capella.	4	50	*The Swan's Bill.*	7	18
Orion's *foremoſt Shoulder.*	5	8	*The Vulture.*	7	35
Orion's *Head.*	5	17	*Lower Horn of the Goat.*	8	3
Orion's *Belt, the Middle.*	5	20	*Swan's Breaſt.*	8	11
Great Dog, Cyrius.	6	31	*Swan's Tail.*	8	31
Little Dog, Procion.	7	22	*Lower Wing of the Swan.*	8	33
Lower head of the Twins.	7	26	Cepheus *Girdle.*	9	25
North Aſellus.	8	23	Pegaſus *Mouth.*	9	28
South Aſſellus.	8	25	Fomahaut.	10	39
Lion's Heart.	9	30	Scheat.	10	48
Lion's Tail.	11	32	Mereha.	10	49
Vindemiatrix.	0	47	*Head of* Andromeda.	11	50
Spica Virginis.	1	8	Caſſiopea's *Chair.*	11	53
Arcturus.	2	1			
Boote's *left Should.*	2	19			
South Ballance.	2	23			

The Uſe of theſe Tables.

1. *Example:* Suppoſe that upon the 31ſt of *December* I find the *Great Dog's* Horary Diſtance from the Meridian (or his Hour) to be 9 Hours and 22 Minutes,

	h.	*m.*
The Comp. of the Sun's Right Aſcenſion for *Decemb.* 31. is,	4	30
The Right Aſcenſion of the *Great Dog* is,	6	31
And the *Star's* Hour (by your *Dial*) is,	9	22
Theſe being added together, make	20	23

From which take 12 Hours, and there reſts 8 Hours and 23 min. for the true Hour of the Night.

2. *Example.*

2. *Example*, Upon the 11th. of *December* I obſerved the Horary Diſtance of the *Bull's Eye* to be 8 Hours and 56 minutes from the Meridian, and I would know the true Hour of the Night,

	h.	m.
Decemb. 11. The *Sun*'s Right Aſcenſion is,	6	00
The Right Aſcenſion of the *Bull's Eye* is	4	17
That *Star*'s Hour is (by the *Dial*)	8	56
Theſe three being added together, make	20	13
From which Subſtract	12	00
There remains	8	13

Which is the true Hour of the Night.

3. *Example.* I obſerved the Hour of *Arcturus* upon the 6th. of *February* to be 24 minutes after 6; and I would know the true Hour of the Night.

	h.	m.
February 6. The Comp. of the *Sun*'s Right Aſcenſion is,	1	58
The Right Aſcenſion of *Arcturus* is	2	01
The *Star*'s Hour obſerved by the *Dial*, was	6	24
The Sum of theſe make	10	23

Which is the true Hour of the Night.

For, This is a general Rule; If you add the *Right Aſcenſion* of any *Star*, The Complement of the *Sun*'s *Right Aſcenſion*, and the *Star*'s Hour, all three together (deducting 12 Hours if the *Sun* be greater) that Sum ſhall be the true Hour of the Night.

For Trial; Let us take the firſt *Example* before going, where upon the 31 of *December* the *Great Dog*'s Hour was 9 Hours 22 minutes from the Meridian----The Complement of the *Sun's Right Aſcenſion* was 4 Hours 30 minutes----And the *Right Aſcenſion* of the *Great Dog* was 6 Hours 30 minutes; theſe three numbers being added together, and 12 Hours abated (becauſe the *Sun* was 20 Hours 22 minutes) there will 8 Hours and 22 minutes remain, for the Hour of the Night, thus:

	h.	m.
Great Dog's Hour	9	22
Complement of the *Sun*'s Right Aſcenſion	4	30
Great Dog's Right Aſcenſion	6	31
Their Sum	20	23
Deduct	12	00
There remains	8	22

Which 8 Hours 23 min. is the true Hour of the Night, as by this and the former Work.

In like manner by theſe *Dials* may be found the Hour of the Night by the *Moon* (and this may be uſeful for ſuch as know not the *Stars*) but they muſt then know the Age of the *Moon*, which any *Almanack* will afford.

The End of the Ninth TRACTATE.

PROJECTIVE DIALLING:

OR, OF

Inſerting the Uſual *FURNITURE*

INTO

SUN-DIALS,

PROJECTIVELY.

The Tenth TRACTATE.

CHAP. I.

Of Furniture in General.

1. A*Zimuths, or 2 Points of the Compaſs*, may be projected into any Dial directly, as the hours were in this manner. Upon the Plain (whereon you drew the Horizontal Dial, and from the ſame Center therein fixed) deſcribe a Circle; and upon it, ſet off from the Meridian Line, each tenth Azimuth by dividing each Quadrant of the Circle into nine equal parts, or each Point of the Compaſs by dividing the ſeveral Quadrants into eight equal parts; and applying the Plain to its firſt poſture, by a Thread from the Center of the Circle, project theſe Azimuths or Winds into the Horizontal Line, making marks in the ſame Line for each one of them, as you did before for the hours. After this, from the Point of the Gnomon, ſet a Thread perpendicularly either upward or downward, which may repreſent the Zenith Line, and is therefore the Axis of all the Azimuths. By this Thread then, and the Points ſigned out in the Horizontal Line, you may project the Azimuths or Winds in the ſame manner as you did the hours before. Or thus: Stretch a Thread from the Point of the Gnomon, to the ſeveral Points of the Azimuths in the Horizontal Line: and note the Nadir Point directly under the Point of the Gnomon, upon ſome object laid there for that purpoſe. Then if with your eye you repoſe the Thread before extended upon the ſame Nadir Point, the ſhadow or appearance of the Thread will ſhew upon the Dial Superficies where the ſame Azimuth is to be drawn. The like muſt be done for every Azimuth or Point of the Compaſs ſeverally.

3. *Almicanthers* may be projected by the Semicircle it ſelf, without any other help. For if you lift up the Semicircle to ſuch a Number of Degrees as anſwers to the Almicanther which is to be inſerted, and apply the Ruler

of it, being in that posture to the Point of the Gnomon and to each Hour-line, or to the several Azimuth Lines, or else to any part of the Superficies which you will, the same Ruler will sign out Points, through which the Almicanthers are to be drawn.

4. *Such Almicanthers as shew the Proportions of Shadows (cast upon Horizontal Plains) to their upright Bodies*, may be projected in the self-same manner, by elevating the Semicircle to such Numbers in the Geometrical Square (which is upon the Semicircle) as answer to the Proportions that shall be required. That Point of the Square which is 3 $\frac{9}{10}$ answers to 18 deg. and is the Crepusculum Line.

¶ These four Particulars may be inserted in this manner generally in all Latitudes alike, and are therefore as Universal as are the former Precepts for the hours. The rest that follow must have particular Tables framed for them, agreeable to every Latitude. The Computation of which Tables may be in such manner as is hereafter shewed.

5. *Parallels of the Sun's Declination*; 6. *Parallels of the Length of the Day*; 7. *Parallels of the beginning of the Twelve Signs*, must first be known what Parallels they are from the Equinoctial, or what Declination they have, and likewise what Altitudes each of them have upon every hour in your own Latitude. The Parallels of Declination are soon found if you determine which of them to put in, as every fifth, or tenth from the Equinoctial, for their Declination is according to their Number. The Parallels of the 12 Signs are these 11 deg. 30 min. for ♉ ♍ ♏ ♓ : 20 deg. 12 min. for ♊ ♌ ♐ ♒ : 23 deg. 30 min. for ♋ and ♑ : the Equinoctial it self serving for ♈ and ♎. Only it must be remembred which Signs are North, and which South, that so they may be placed either above or below the Equinoctial. The Parallels for the days length of 16, 15, 14, 13, 12, 11, 9, 8 hours, of what Declination from the Equinoctial they are, must be searched out (as they shall agree to each particular Latitude) in this manner: As the *Radius*, to the Sine of half an hour, that is to the Sine of 7 deg. 30 min. So is the Co-tangent of your Latitude, to the Tangent of the Declination of that Parallel, which being North, makes the day 13 hours long, or being South makes it 11 hours long. So likewise, as the *Radius*, to the Sine of two half hours or 15 deg. 00 min. So is the Co-tangent of your Latitude, to the Tangent of that Parallel that makes the Day 14 or 10 hours in length. And as the *Radius* to the Sine of 3 half hours or 4 half hours, that is 22 $\frac{1}{2}$ deg. or 30 deg. So is the Co-tangent of your Latitude to the Tangents of the Declinations or Parallels that make the Day of 15 and 9, and of 16 and 8 hours length, *&c.* A large Table to this purpose you have ready calculated for all Latitudes, from 16 to 90 deg. in the *Sixth Tractate* among the Tables there.

Having found such Parallels of Declination as you mean to use for the three former Purposes, you are then to compute upon each of them, the Altitudes of the Sun for every hour. And amongst many ways, let this be one, which is general to them all, and best wrought by the natural Canon in this manner.

First, for the Equinoctial, which is the Line that passeth through the beginning of ♈ and ♎, and from whence all Declinations are counted, as also the Line upon which the Day is every where 12 hours long, the Altitudes for each

each hour may be found by this Proportion. As the *Radius*, is to the Cosine of your Latitude; So are the Sines of 1, 2, 3, 4, 5, 6 hours, to the Sines of the Altitudes of the hours 7, 8, 9, 10, 11, 12, in the Morning, or of 5, 4, 3, 2, 1, 12, in the Afternoon, when the Sun is in the Equinoctial. At 6 the Sun is just in the Horizon. Now for inserting the Equinoctial Line upon a plain Superficies any two Altitudes for two such hours as are at a convenient distance, will serve turn; because the Equinoctial being a great Circle of the Sphere, is projected upon a Plain into a strait Line, and two Points are sufficient to direct where to draw a strait Line upon a Plain. But if the Superficies be manifold or uneven, all the Altitudes must be made use of, or two Altitudes and the Point of the Gnomon will shew the Equinoctial Superficies, and so it may be projected with a Thread.

Secondly, For all other Parallels this course may be taken.

1. Find out the Sines of the Altitudes of 6 a Clock in all North Parallels by this Proportion; As the *Radius* to the Sine of your Latitude; So is the Sine of every Declination, to the Sine of the Altitude of 6 a Clock in that Parallel of Declination. By this Sine found, and entred into the Canon of Sines, you may get the Altitude of 6 for every Parallel.

2. For the same North Parallels, add the Declination of your Parallel to the Complement of your Latitude, the Sum will be the Altitude of the Sun for 12 a Clock in that Parallel. Then out of the Sine of this Altitude of 12, take the Sine of the Altitude of 6, reserving the *Difference*.

3. As the *Radius*, to this Difference; So the Sines of 1, 2, 3, 4, 5 hours, to several fourth Numbers, or Sines.

4. To every one of these fourth Numbers, add the Sine of the Altitude of 6; So shall the several Sums produce the Sines of the Altitudes for every hour between 6 and 12.

5. Take as many of those fourth Numbers as you can, out of the Sine of the Altitude of 6; so shall the several Remainders make the Sines of the Altitudes of such hours as are between 6 and Sun-rising, or Sun-setting.

6. Take the Sine of the Altitude of 6, out of all such of the fourth Numbers, as are bigger than it, so shall the Remainders give the Sines of the Altitudes of the Sun upon such South Parallels which have the like Declinations from the Equinoctial, that these North Parallels have.

¶ Thus having found out the Altitudes required in each kind, they must be ordered into Tables, and reserved for use. And if according to the usual manner of working by the Semicircle, you insert from the Point of the Gnomon into the particular hours such Altitudes as your Tables afford, you shall find pricks through which to draw each requisite Parallel. But, to save this labour, there are in the *Sixth Tractate*, Tables for this Purpose ready calculated for several Degrees of Latitude, and for the Sun's entrance into every Sign of the Zodiack, and every 10th Degree thereof.

CHAP. II.

Of Signs of the Ecliptick *Ascending, Descending, and Culminating.*

IF you would insert the Signs into the Hour-lines, you must find out what Altitudes the Intersections of the Ecliptick have with the hour Circles (two of them at the least, to set them upon a Plain, but more are better, that they

they may ſerve in all Caſes, and to all Superficies) at that moment of time, when the beginning of any Sign is Aſcending, Deſcending, or Culminating, which will be found a hard Calculation. It would be as eaſie to find what Altitudes the Ecliptick hath at thoſe times with ſome chief Azimuths. But the moſt eaſie way, that I know, will be to find out what Amplitude the beginning of every Sign, riſing or ſetting, hath, and what Altitude the Ecliptick at the ſame time cutteth upon the Meridian. And for Signs Culminating, it muſt be enquired what Altitude the beginning of each Sign hath when it is in the Meridian, and what Amplitude alſo it hath at the ſame time upon the Horizon.

Then for *Signs Aſcending*. If ♈ aſcend, then is the Amplitude 00, and ♑ is in the Meridian, and ſo the Meridian Altitude of ♑ is the Altitude of the Ecliptick upon the Meridian whilſt the firſt Point of ♈ is aſcending. So if the firſt Point of ♎ be aſcendant, then likewiſe the Amplitude will be 00, and ♋ will be in the Meridian; ſo that the Meridian Altitude of ♋ is the Altitude of the Ecliptick upon the Meridian, whilſt the beginning of ♎ is aſcending. For the other Signs, to know what Altitude the Ecliptick cuts upon the Meridian at their aſcent above the Horizon, there muſt be inquired; 1. Their Amplitude; 2. The Oriental Angle, or the Angle made between the Ecliptick and Horizon at the ſame time.

1. The Amplitude is thus known; As the Sine of the Latitude, is to the Sine of the Declination of the beginning of any Sign; So is the *Radius*, to the Sine of the Amplitude from the Eaſt. This for North Signs being added to 90, for South Signs ſubducted from 90, produceth the Amplitude reckoned from the South.

2. The Oriental Angle, is thus found. As the Co-ſine of the Declination of the Point aſcending, is to the Sine of your Latitude; So is the *Radius*, to the Sine of the Angle made between the Meridian that paſſeth through the Point aſcending, and the Horizon. This Angle added to the Angle made by the ſame Meridian and Ecliptick, gives the true Oriental Angle. Now the Angles made by the Ecliptick and Meridians that paſs through the beginning of each Sign, are theſe ♈ 113 deg. 30 min. ♉ ♓ 110 deg. 38 min. ♊ ♒ 102 deg. 16 min. ♋ ♑ 90 deg. 00 min. ♌ ♐ 77 deg. 44 min. ♏ ♍ 69 deg. 22 min. ♎ 66 deg. 30 min. Theſe, I ſay, are the Angles before mention'd, which in theſe Northern Latitudes, and while they are in the Aſcendant, do look upwards from the Horizon toward the Zenith and North Pole, or towards the Arch included between them. But their Supplements muſt be taken in South Latitudes. And although the Oriental Angle do fall out to be obtuſe, and the Tangent of it is uſed in the next Work, whereas Tangents ſerve no further than 90, it is to be remembred here that any Arch and the Supplement thereof have one and the ſame, as Sine, ſo Tangent, and Secant alſo.

3. As the *Radius*, to the Tangent of the Oriental Angle; So the Sine of the Amplitude from the South, to the Tangent of the Ecliptick's Altitude upon the Meridian. Now theſe Altitudes upon the Meridian being computed for ♈ ♉ ♊ ♋ ♌ ♍ ♎ will be ſufficient; for ♓ aſcending, the Ecliptick hath the ſame Meridian Altitude that it hath when ♉ aſcends: and ♒ the ſame with ♊, and ♑ with ♋, ♐ with ♌, ♏ with ♍.

¶ The two Tables then of Amplitudes and Meridian Altitudes being framed, you may by them inſert the 12 Signs aſcending in this manner with leaſt trouble, though enough too. Piece out your Horizontal Line by a

returning

returning Thread where need is; and upon it project the Amplitudes of the aſcending Signs from the South, amongſt the Morning hours. They muſt be protracted firſt upon a Plain or paſt-board as the hours and Azimuths were before, and from thence tranſmitted to the Horizontal Line, and marks or knots ſet thereunto. Then if the Meridian Line be there all is well; but if it be not upon the Dial Superficies, you muſt, for a time, draw or ſtretch one in the Air by a Thread placed in the plain of the Meridian in ſuch manner as that it may receive what is now to be inſerted into it. Into the ſame Meridian therefore, by help of your Semicircle, inſert the ſeveral Meridian Altitudes of the Ecliptick, and ſet marks at them. After this, you may without any great difficulty, project the ſeveral Poſitions of the Ecliptick, thus: Stretch a Thread, fixed at one end to the Point of the Gnomon, to the ſeveral marks ſet in the Horizontal Line, and at every ſuch extent let your eye repoſe the Thread upon that point in the Meridian which anſwers there to the ſame Sign that the Thread was extended unto in the Horizontal Line, ſo ſhall the ſhadow of the Thread ſhew you upon the Dial, where the Line for that aſcendant Sign is to be drawn. And ſo having projected them all (12 in number) you may at the Eaſt end, among the Morning hours, write *Signs Aſcending* with the Characters of thoſe ſet upon each of them, which properly belong unto them: and, among the Evening hours, write *Signs Deſcending*, ſetting upon each Line the Characters of thoſe Signs that are oppoſite to the former, becauſe when any Sign is aſcending, the oppoſite is deſcending.

Deſcending Signs then are put in by the ſame Work that aſcending are.

Note, That in Dials that look towards the North, you muſt by your Semicircle project the ſame Meridian Altitudes upward, above the Horizontal Line, and not downwards, as in Dials looking towards the South.

9. For *Signs Culminating*. You muſt firſt find their Meridian Altitudes, which is eaſily done for the beginnings of every Sign. For having their Declinations before ſet down, you muſt, if they be North Signs, add their Declinations to the height of the Equinoctial, or to the Complement of your Latitude, or in South Signs, ſubduct the Declinations out of the Complement of your Latitude, ſo the Numbers produced will be the Meridian Altitudes of the beginnings of the twelve Signs. Secondly, you muſt ſeek what Amplitudes the Ecliptick hath, when the beginnings of the twelve Signs are in the Meridian. To which purpoſe alſo, the acute Angle made between the Meridian that paſſeth through the beginning of each Sign, and the Ecliptick, muſt be had in readineſs: and they are theſe, ♈ ♎ 66 deg. 30 min. ♉ ♍ ♏ ♓ 69 deg. 22 min ♊ ♌ ♐ ♒ 77 deg. 44 min. ♋ ♑ 90 deg. 00 min. And likewiſe it muſt be noted, that any Sign from ♋ to ♑ being in the Meridian, the *Ortive Amplitude* of the Ecliptick from the South is leſs than 90 deg. the *Occaſive* more. But any Sign from ♑ to ♋ poſſeſſing the Meridian, the *Ortive Amplitude* is from the South more than 90 deg. the *Occaſive* leſs. Now then the Amplitude is found by this Proportion; As the *Radius*, is to the Sine of the Meridian Altitude of the beginning of any Sign; So is the Tangent of the Angle at the Meridian (ſet down before for every Sign) to the Tangent of the Ecliptick's Amplitude at that time from the South. The Amplitudes *Ortive* of the Ecliptick when ♋ and ♑ are in the South are always 90 deg. and if you enquire the

Ortive Amplitudes of ♌ ♍ ♎ ♏ ♐, their Supplements are the Ortive Amplitudes for ♊ ♉ ♈ ♓ ♒, remembering the Cautions given before. And the Ortive Amplitude of the Ecliptick from the South when any Sign is culminating is equal to the Occasive Amplitude of the Ecliptick from the South when that Sign that is as much distant from ♋ as the fore-named Sign was, is culminating.

¶ The Tables of the Ecliptick's Amplitudes from the South, and Meridian Altitudes being fitted, you must now accommodate your Horizontal and Meridian Lines as you did before for ascending Signs; and then among the Morning hours from a plain Board or past-board, project your Amplitudes into the Horizontal Line for the 12 Signs, and their Meridian Altitudes into the Meridian Line by your Semicircle. And being thus prepared you may project the Eclipticks severally into your Dial Superficies, and Character each Line with that Sign that belongs unto it, and with the Character of the opposite Sign that is in *Imo Cœli* at the same time.

CHAP. III.

By Help of the Parallels of the Length of the Day may be inscribed these that follow.

10 *Hours from Sun-rising.* 11 *Hours from Sun-setting.* 12 *Planetary Hours.* 13 *The six Houses that are above the Horizon.*

THE Eastern part of the Horizontal Line is the beginning of the hours from Sun-rising, as the Western part is the beginning of the hours numbred from Yesterday's Sun-set. Look then for any two Parallels of the Days length that are of equal or even number (and not odd) as 8, 10, 12, 14, 16: and if your Dial be described upon a Plain, count upon any two of those Parallels the first hour from the Horizontal Line, and draw a strait Line through those two Points: the same Line if it be from the East part of the Horizon is the first hour from or after Sun-rising, if from the West it is the 23 hour from Yesterday's Sun-set. So the right Line drawn through these two second Points from the East part of the Horizon is the second hour from Sun-rising, or from the West part it will be the 22 hour from Yesterday's Sun-set, which are accordingly to be figured. And so of all the rest.

For the Planetary hours, choose out the Parallels of the day's length 15 and 9 hours; and in the first take each 5 quarters from the Horizon, in the second each 3 quarters, and draw strait Lines through them if the Superficies be plain, the same Lines are the Planetary hours, the Meridian being 6, the West Horizon 12. But in all these, if the Superficies be not plain, but either many Plains together, or one curved and irregular, you are to stretch a Thread so as that you may see the two Points for each hour before-mentioned, and the Point of the Gnomon altogether upon the Thread; then shall the shadow of the Thread in that Position express where every such Hour-line must be drawn.

For the Houses, find out by your Semicircle, that Point in the hour of 12 that is level with the Point of the Gnomon. If then your Dial be upon a plain Superficies, draw strait Lines from the fore-named Point through each second Hour-point in the Equinoctial Line on both sides 12; the same Lines

shall

ſhall be the 6 Houſes above the Horizon, and the Meridian Line is the tenth Houſe. But if the Superficies be curved, hold a Thread ſo as that you may ſee through it the foreſaid two Points of each Houſe, together with the Point of the Gnomon; for then the ſhadow of the Thread will ſhew to your eye where each Houſe is to be drawn.

CHAP. IV.

14. *Of the Riſing, Culminating, and Setting of any Fixed Star.*

Suppoſe the Star to be *Lucida Pleiadum.*

THE Declination of the *Star* Northward is 23 deg. 00 min. the right Aſcenſion 51 deg. 42 min. Firſt then, get the Semidiurnal Arch of the *Star* by this Proportion, As the Co-tangent of your Latitude, to the Tangent of the *Star*'s Declination: So is the *Radius* to the Sine of the *Star*'s Aſcenſional difference, which being added to 90 deg. (becauſe the Declination is North, elſe it ſhould be ſubſtracted) gives the *Star*'s Semidiurnal Arch. For *London* it would be 122 deg. 15 min. This taken out of the *Star*'s right Aſcenſion, leaveth (289 deg. 27 min.) the right Aſcenſion of *Medium Cœli* when the *Star* is riſing. Or the Semidiurnal Arch added to the *Star*'s right Aſcenſion, gives (173 deg. 57 min.) the right Aſcenſion of *Medium Cœli* when the *Star* is ſetting. Then laſtly alſo, the right Aſcenſion of the *Star* is the right Aſcenſion of *Medium Cœli* when the *Star* culminates. Now having gotten theſe right Aſcenſions, you may get the Points of the Ecliptick, their Declinations, and the Angles of Ecliptick and Meridian anſwerable, in this manner. As the *Radius*, to the Sine of 66 $\frac{1}{2}$ deg. So is the Tangent of right Aſcenſion, to the Tangent of the Point of the Ecliptick anſwerable. As the *Radius*, to the Sine of right Aſcenſion; So the Tangent of 23 $\frac{1}{2}$, to the Tangent of the Declination of that Point to which the right Aſcenſion belonged. As the *Radius*, to the Sine of 23 $\frac{1}{2}$ deg. So the Co-ſine of right Aſcenſion, to the Co-ſine of the acute Angle made by the Ecliptick and Meridian.

Then note, that if the right Aſcenſion of *Medium Cœli* be in the ſecond or third quarters of the Equator, the *Ortive Amplitude* of the Ecliptick from the South is leſs than 90 deg. the *Occaſive* more. But if the right Aſcenſion be in the firſt or laſt Quarters, then is the *Ortive Amplitude* more than 90, the *Occaſive* leſs.——Having found *Medium Cœli*, ſay, As the *Radius*, to the Sine of 23 $\frac{1}{2}$; So the Sine of *Medium Cœli*, to the Sine of the Declination of *Medium Cœli*. By this Declination compared with the Altitude of the Equator, you may alſo find the Altitude of *Medium Cœli*, which is the Meridian Altitude of the Ecliptick. Then again, ſay, As the *Radius*, to the Sine of the Eclipticks Meridian Altitude; So is the Tangent of the Angle between the Ecliptick and Meridian, to the Tangent of the Ecliptick's Amplitude.

In this manner alſo may the appulſe of any Fixed *Star* to any Azimuth, or Almicanther, or Meridian, or any other ſtanding Circle, be computed and inſerted; If namely, the Situation of the Ecliptick at that ſame moment be projected upon the Dial.

¶ Theſe being found, will help to put in ſuch Lines as ſhew the *Star*'s Aſcenſion above the Horizon, Deſcenſion, and Culmination. The manner of

of putting them in, is the very ſame that was uſed before for inſerting the Signs of the Ecliptick *Aſcending*, *Deſcending*, *Culminating*, ſo that more Words about it will be needleſs.

These are the principal things wherewith Sun-Dials are uſually furniſhed. If theſe be well underſtood, it will not be hard to inſert the Coſmical, Acromical, or Heliacal riſing and ſetting of Stars, or any ſuch like requiſites. All the ſeveral uſes of each kind of Lines is ſhewed by the ſhadow of the Point of the Gnomon, as it creepeth along through them.

CHAP. V.

Other Precepts concerning the Inſerting or Projecting of the Furniture into Sun-Dials.

I. *Of the* Equator, *and two* Parallels *thereto.*

THE Parallels of the Equator are uſually diſtinguiſhed by theſe three Names. 1. Parallels of Declination. 2. Parallels of Signs. 3. Parallels of the length of the Day. Now all theſe Parallels being but of one kind though of ſeveral Relations, muſt be put into a Dial in one and the ſame manner; only you are to find which Parallels upon the Planiſphere are anſwerable to each of theſe, and this is ſhewed before in *Chap.* 3. *Sect.* 5.

Now in general alſo be admoniſhed, that all things which are inſerted by this manner of Work, are done by their Altitudes above the Horizon; and if they be great Circles,ſuch as are the Equator, Eclipticks, Azimuths and Horizon, then will two Altitudes in any two hours of your Projection ſerve to inſert ſuch into any Plain,becauſe every great Circle projected upon a Plain becomes a ſtrait Line, and two Points are enough to ſhew where a ſtrait Line is to be drawn; But for every leſſer Circle you muſt have as many Points of Altitude as there are hours, through which Points your leſſer Circle is to be deſcribed with a light hand.

1. Therefore if you would put in the Equinoctial, chooſe any two hours upon your Plain (of as good diſtance as may be, that your Work may be the truer) and look upon your Planiſphere what Altitudes the Equinoctial Circle hath upon thoſe two hours (as which to do is ſhewed before, *Sect.* 6. *Chap.* 3.)

Then with your Semicircle expreſs thoſe two Altitudes upon the ſaid two hours of your Dial, and you ſhall have two Points through which if you draw a ſtrait Line, it ſhall be the Equinoctial Line, upon which you are to fix the Characters of ♈ and ♎.

2. To draw any of the Parallels of Declination,look upon your Planiſphere which Parallel anſwers to it,and then look there what Altitudes the ſame Parallel hath upon every hour (*per Prop.* 6. *Cap.*3.) and with your Semicircle expreſs thoſe Altitudes upon the Plain, each Altitude in its proper hour; So ſhall you have Points in every hour, through which the ſame Parallel is to be drawn; If they be every 10*th.* you muſt number them by 10, 20, *&c.* above and below the Equator. The ſame is to be done for the Parallels of the beginnings of the 12 Signs, upon which when they are drawn you muſt ſet the Characters of the 12 Signs in their proper places;

And

And three for the Parallels of the length of the day, upon which you are to write the numbers of the length of the day, nor ſhall I need to make more words about them.

II. *Of the* Horizon *with the* Parallels *thereof called* Almicanthers, *and of them ſuch as ſhew the three* Proportions of the length of the Shadow to any upright Body : *Of the* Azimuths *or* Vertical Circles, *and (among them) of ſuch as ſerve for the* Points *of this* Compaſs.

1. The Horizon was inſerted at the firſt beginning of the Work, and is repreſented by the Horizontal Line lying wholly in the ſame Level with the Apex of the Gnomon.

2. The Almicanthers or Parallel of the Sun's Altitude above it may be inſerted by the Semicircle alone without the Planiſphere; For if upon every hour you expreſs by your Semicircle one and the ſame Altitude (*v.* 9. the 10*th.* deg. of Altitude) and through thoſe Points draw an Oblique Line as the manner is, the ſame Line will ſtand for the *(10th.)* Almicanther required; and ſo of the reſt.

3. For ſuch Almicanthers as ſhew any common proportion between the ſhadow and the upright Body; The eaſieſt way will be to have marked out upon your Semicircle, ſuch Almicanthers as you deſire to put in, or which is better and more handſom you may deſcribe in each of the two Quadrants which do make up the Semicircle, two Geometrical Squares, the ſides whereof may be divided into 120 equal parts, and numbred as the uſual manner is, and is expreſſed in the Figure of the Semicircle ordinarily, ſo ſhall you have all proportions fitted to your hand. As if I would put in that Almicanther which ſhews the ſhadow to the upright Body to be as 5 to 3. that is, as 120 is to 72; count 72. from the Semidiameter of the Semicircle towards the middle Point of the Square, and then I inſert that Point into every of the hours upon the ſame, and accordingly to draw a curved Line through them, and write upon it $\frac{5}{3}$ or *ſuperbipartiens tertias*: But if I would inſert the contrary proportion, as of 3 to 5, then I count upon the Square the former number 72 from the Diameter of the Semicircle towards the middle Point of the Square, and then I inſert that Point as before, and write upon the Almicanther $\frac{3}{5}$ or *ſupertripartiens quintas*. Now whenſoever the Apex of the Gnomon comes into the firſt of theſe Lines (then the ſhadow 3 $\frac{9}{10}$ upon the Square is the Crepuſculum Line or 18th Almicanter which will ſhew the Twi-Light upon the oppoſite Parallel) then you may conclude that the ſhadow of an upright Body or Building being caſt upon a flat level plain, is in proportion to the upright Body as 5 to 3; that is, if you divide the ſhadow into 5 equal parts, three of the ſame parts will give you the Altitude of the upright Body; So in the ſecond Example, if you divide the Shadow into 3 equal parts, five of the ſame parts will give the length of the upright Body; And thus the ſhadow of the Sun performs the uſes of the Geometrical Square.

4. If you would put the Azimuths into your Dial, lay the Ruler upon your Planiſphere to that Azimuth which you mean to put in, then obſerve any two hours (the further diſtant the better) where they interſect the Ruler, and count the Altitude of their Interſections from the Horizon, and inſert them by help of your Semicircle into the Dial, each Altitude into its proper hour; ſo ſhall you have two points through which you may draw your Azimuth;

and so must you do with the rest of them, and number them from the South by Tenths or Fifths, according as you put in every Tenth or Fifth.

The same course is to be taken for the Points of the Compass which are also Azimuths, and each 11 ¼ deg. of the Horizon represents them, for there are 8 only in a Quadrant, now 8 is contained in 90 degrees 11 ¼ times, so that no more needs to be said of these; they are to have their proper names signified by their Letters, as the first, second, and third from the South, Eastward, are noted by these Letters S b E : S S E : S E b S : &c. and so the rest as most know.

III. *Of such things as concern the moving of the* Ecliptick. *And* 1. *of the putting in such Lines as shew what* Signs *are at any time* Rising *or* Setting *(commonly called* Signs Ascending *or* Descending.) 2. *Such Lines as will shew what* Signs *are at any time in the* Meridian, *commonly called* Signs Culminating.

See the Figure of the Horizontal Dial.

1. Supposing any Sign to be descending you are taught by your Planisphere *(Prop.7. Chap.3.)* to know what degree of the Ecliptick is in any Hour-circle: Choose you then 2 Hour-circles answering to such as are upon your Plain of a competent distance, and enquire what degrees of the Ecliptick are in them at the same time, and find out their Altitudes by the same 7th Proposition, then by your Semicircle insert those Altitudes into their proper hours upon the Plain, and from the two points inserted draw a strait Line (because the Ecliptick is a great Circle) which shall be the Line, shewing when such a Sign is descending, and the opposite Sign ascending; Wherefore upon that Line you must set (suppose ♉ were descending) ♉ D, and the opposite to it ♏ A. Or better. The Signs ascending may be characterized upon your Dial, at the West end of the Line with this written amongst them [*Signa Ascendentia*] and the Signs descending at the East end of the Line with [*Signa Descendentia*] written to them.

2. The very same course you are to take for the Signs culminating, if you make use of the 8th. Proposition of the former Chapter, so that it shall not be needful to make more words of them; and they must have set upon them the Characters of the 12 Signs with [*Signa Culminantia*] written amongst them at the one end of the Lines, and the opposite Characters at the other end with [*Signa in Imo Cœli*] written.

Concerning the using of these Lines when they are drawn, consider the Caution on the opposite sides inserted.

IV. *Of the* Hours *of other* Countries.

Horæ ab ortu; *may be put in* per reclin. & declin. *if a Thread be extended,* ab Apice gnomi, ad declin. in lin. horizontali & projiciatur ita ut tangat Almicant. reclinationis.

Besides the hours which we have already described which only are in use amongst us, and are called Astronomical, some Countries number their hours from the Horizon, and that three ways, therefore are called by three names usually, *Horæ ab ortu*; *Horæ ab Occasu*; *Horæ Planetariæ vel Judaicæ*, the two first kinds are equal hours, as those with us are, and of the same length really, but are numbred from 1 to 24. that is from one Sun-rising to the next, and so from one Sun-setting to the next, but the last are numbred from Sun-rising to Sun-set, every day being equally divided into 12 hours, which makes the hours of several days to be unequal one to the other, whence they are also call'd *Horæ inæquales*, How to put these into Dials, if the Parallels of the length of days be drawn before, then there is no difficulty. For,

1. The

1. The hours *ab Ortu*, begin from the East part of the Horizon; look therefore upon your Dial for two of those Parallels on which the day makes an even number of hours, as for Example 16 and 8. upon the first of which the Sun riseth at 4 in the Morning, upon the latter at 8; Then observe again upon these two Parallels the Intersections that every Hour-line of the Dial makes upon them, as next to 4 and 8. through which the Horizontal Line passeth, you shall see the Section of 5 and 9 to follow, and then 6, and 10, *&c.* If now through the Intersections of 5 and 9 with those Parallels you draw a strait Line, the same shall be 1. hour *ab Ortu*; and one drawn from the Intersections of 6. and 10. shall be the second hour, and so of all the rest. But if the forenamed Parallels be not drawn, you must prick down where they should be drawn, as was before shewed in this Chapter, and so make use of those Points for the same purpose, which is all one with the former.

2. The hours *ab Occasu*, are in like sort to be dealt withal; for if you make use of the same Parallels before mentioned, as 16. and 8. where the Sun sets upon the West end of the Horizontal Line on the Dial, in the first at 8. in the latter at 4 Clock, which setting is to be accounted the 24 hours, then it is evident that in the same Parallels 7 a Clock and 3 are the 23 hour, 6 and 2. are the 22 hour, 5 and 1. are the 21 hour, and so of the rest; wherefore if from these mentioned pairs of hours where they intersect the Parallels, you draw strait Lines (upon Plains not else) they shall be the 23.22.21 hours *ab occasu hesterno*, and the West end of the Horizontal Line is the 24 hour *ab occasu*.

3. The Planetary hours are to be dealt withal in this manner, upon your Planisphere, choose such Parallels of the days length as are easiest to be divided into 12 parts, such as are 15 and 9, in the first of which $1\frac{1}{4}$ of an hour makes $1\frac{1}{2}$ part of a Planetary hour of the day, $2\frac{2}{4}$ hours makes two Planetary hours, $3\frac{3}{4}$ hours makes 3 Planetary hours, *&c.* In the latter $\frac{3}{4}$ of an hour makes one Planetary hour; $\frac{6}{4}$ or $1\frac{1}{2}$ hour makes 2 Planetary hours, $\frac{9}{4}$ or $2\frac{1}{4}$ hours makes 3 Planetary hours, and so forward. If then the said Parallels of 15 and 9. be drawn upon the Dial, you may prick on them the places where the Planetary hours should pass, but if those Parallels be not drawn you must then take the Altitudes of these Sections, or imagine points upon your Planisphere, and express them upon the answerable hours and parts of hours upon your Dial-plain, you shall then find 2 points for each Line of those Planetary hours to be drawn, and accordingly draw them, which if they fall out just, should pass through the hours upon the Equinoctial Line; but this is not altogether to be expected, because the Planetary hours are not really great Circles upon the Sphere, and so not absolute strait Lines upon the Dial, though near enough to give an estimate of such a Division of the day, you may therefore for more accurateness draw them a little bending, that so they may pass through the hours of the Equinoctial. The 12 a Clock is always 6, the rest numbred accordingly.

V. *Of the Six Houses above the Horizon, and how to protract them also.*

From the Point where 12 cuts the Horizontal Line to the hours of 8.10.12. 2. 4. in the Equinoctial Circle draw right lines, and they are the 6 Houses above the Horizon, those below are not to be shewed by the Sun, who is then below too: The West end of the Horizon is the beginning of the Seventh House, the next Line begins the Eighth House, the next the Ninth House, the Meridian the Tenth House, and so forward, according to which rate they are to be numbered.

VI. *Of the Horizon of any City or place, whose Longitude and Latitude is known, and how to insert it into a Sun-Dial.*

The ſpeedieſt way that I can pitch upon,is this. After you know what kind of Longitude (whether Eaſt or Weſt) and what kind of Latitude (whether North or South) the Horizon or Place hath, and conſequently having conſidered whether the Eaſt or weſt part of the Horizon be to be inſerted, or both Eaſt or Weſt (for all theſe caſes may fall out.) Having I ſay conſidered of all theſe things fully before hand, you may reſpectively order your Work, as for an Eaſterly Place whoſe Latitude is Northern, this Example will ſhew. Suppoſe I would put the Horizon of *Conſtantinople* into a Dial. Firſt, I know *Conſtantinople* to have a North Latitude of 43 deg. and that it differs from the Longitude of *London* 2 hours 16 min. and that towards the Eaſt: Now becauſe it lies Eaſtward from us, therefore the Sun riſeth in the Equinoctial, and ſetteth there alſo before it doth with us; and this riſing in the Equinoctial before us, is ſo much in time as the difference of Longitude comes to, *viz.* 2 hours 16 min. If therefore you deſcribe the Equinoctial Circle upon your Dial (both above and below your Horizontal Line) and then either on the Eaſt part of it count the difference of Longitude from the hour of 6 always, and (in the Example here given) above the Horizontal Line on the Eaſt part (becauſe the Sun riſeth with them before us) or again, you may below the Horizontal Line on the Weſt part (nothing is to be above the Horizontal Line in any part) count upon the Equinoctial the ſame difference of Longitude from 6 a Clock, thus is 16 min. before 4 a Clock on either part, or 3 a Clock and 44 min. ſo ſhall one of theſe two points (that which is moſt convenient) and the Gnomon give you two points, whereby to project the Horizon of *Conſtantinople*, and that muſt be extended ſo far as the projection of the 2 Tropicks and Horizontal Line do go, that ſo it may ſerve for all times of the Year which are poſſible. If in this Example on the Eaſt part the Projection fall quite out of thoſe forenamed limits, it muſt there be quite neglected, and only put on upon the Weſt part of the Dial.

How to find a Third point. It may be done many ways upon your own Meridian thus: As the *Radius* is to the Co-ſine of the difference of Longitude; So the Tangent of the Latitude of *Conſtantinople*, is to the Co-tangent of the Arch of our Meridian intercepted between the North Pole (in this Example) and the North part of the Horizon of *Conſtantinople*, or from the South Pole, or South part of that Horizon. If therefore you ſtretch a Thread into the Air that may lie on the Planities of your Meridian, you may by your Semicircle inſert this point; But firſt you muſt conſider how far it is from this point to your Zenith: If therefore (in this Example) it be the point of the North part of your Meridian, add the Complement of your Latitude to the intercepted Arch before found; if it be the South point of your Meridian, or of the Horizon of *Conſtantinople*, then ſubduct the Complement of your Latitude out of the forenamed Arch, ſo ſhall you get the diſtance of this point of your Meridian from your Zenith, the Complement or exceſs whereof is, the Altitude or Depreſſion from your Horizon. Afterwards by your Semicircle you may put it into the Meridian Line or extended Thread, by counting the Complement of that ſame diſtance, or the Altitude upon the degrees of your Semicircle.

Now

Now then by the point before found in the Equinoctial, and by this point thus found in the Meridian, and by the point of the Gnomon; I say by these 3 points may the Horizon of *Constantinople* be inserted; and so the Horizon of any other Place.

2. *Another way to find two Points for the same purpose, upon two Hour-Lines.*

Take any hour (as 9 a Clock in the Morning) count the distance of it from 6 (3 hours or 45 degrees) and because the hour is West of 6 a Clock in the Morning, but the place East, add the 3 hours to the difference of Longitude, which is 2 hours 16 min. the Sum is 5 hours 16 min.

In general get the difference of Longitude between the Section of your places Horizon (which Section will either be East or West) with the Equinoctial, and the hours, that is, get the Arch of the Equator contained between them.

Then say, as the *Radius* is to the Co-tangent of the Latitude (43 deg.) of the Horizon (of *Constantinople*) so is the Sine of (79 deg.) that Arch of the Equator to the Tangent of an Arch (46 deg. 38 min.) of the Hour-circle of 9 contained between the Equator and the same Horizon: And because the Latitude of *Constantinople* is North, therefore the Arch falls upon the South side of the Equator: So that if such a point, or degree were inserted upon that Hour-circle of 9, then was one point found. Now to insert it we must know what Altitude or Depression that point bears from our Horizon, which to find by calculation, we have first the Complement of our Latitude, which Complement is 38 deg. 30 min. Secondly, The distance of that point of the Circle of 9 from the North Pole, that is 90 deg. and 46 deg. 28 min. or 136 deg. 28 min. And Thirdly, The Angle of the hour of 9 from the Meridian, which is 45 deg. that is to say 2 sides, and the Angle comprehended by them; so that the Base, or third side (whose Complement is here required) may be found. Having then found this Altitude or Depression (which in the present Example) is 15 deg. 20 min. it may be inserted into the hour of 9 by the Semicircle. And in the same manner may another point be inserted into another hour. These two points then with the point of the Gnomon (3 in all) will serve to project the Horizon required.

Upon the hour of 6 a point may be found more easily, and the Altitude or Depression of it: First, for the point in the Hour-circle of 6: As *Radius* is to the Co-tangent of the Latitude of *Constantinople*; So is the Sine of the difference of Longitude to the Tangent of 30 deg. 57 min. an Arch of the hour of 6 comprehended between the two Horizons, ours and theirs. This Arch (in this Example) must be added to 90 deg.. So the Sum gives the difference of that Section upon 6 from the North Pole: But then as the *Radius* is to the Sine of our Latitude; So is the Sine of that (30 deg. 57 min.) Arch of 6 a Clock to the Sine of the (27 deg. 59 min.) Depression of the Section of *Constantinople* Horizon with our 6 a Clock Line-depression I say, because the point of Intersection is below the Horizon of *London*.

Depression is 28 *deg. Latitude* Constantinople 43 *deg. Dif. Long.* 34 *deg. Declination South East* 83 *deg.* 00 *min. Reclination North* 65 *deg.* 40 *min.*

3. *Another way to put in such an Horizon.*

First, get the Declination (83 deg. 00 min. South East) of it, and the Reclination (65 deg. 40 min. North) or Inclination, with the Coast where-

to it declineth. This Work may be performed by a Spherical Triangle made by the Poles of the Equator and of the two Horizons of *London* and *Constantinople*. Then having found these things; you may insert them thus. First, from the East point of your Horizon, count the Declination to the true Coast, and insert it into the Horizontal Line, for that shall be one point where *Constantinople* Horizon is to pass. Then again from the Meridian point insert into the Horizon (to the true Coast) the same Declination; so that this point of the Declination from the former may be distant 90 deg. To this last point having relation also to the point of the Gnomon, stretch a Thread in the Air, or draw a Line, that may lie in and represent the Azimuth passing through those two points (which a perpendicular Thread reposed upon those two points will direct you) then by your Semicircle project into this Azimuth Line or Thread the Reclination from the Zenith of your place, either above or below your Horizon, as you shall discern the Position of it to require. So then, by this means you have another point where through the same Horizon must pass. These two therefore with the point of the Gnomon will serve to project the same Horizon upon all Superficies that shall be found to stand in the way.

Another way for the same.

When the Parallels and points are drawn first upon the Dial, with the hours you may put in any Horizon without great trouble, thus. The West part of *Constantinople* Horizon; The difference of Longitude is 34 degrees, therefore the Sun in the Equinoctial sets 2 hours 16 minutes with them before it sets with us. The West point therefore of that Horizon is upon the Equator at 3 hours 44 min. this is one point. Then find another point upon some other Parallels as ♋ or ♑, let it be ♑, on the shortest day at *Constantinople* the Sun setteth at 4 hours 24 min. that is the day is then 1 hour 36 min. shorter than in the Equinoctial, and setteth 1 hour 36 min. sooner: Therefore from the Horizontal point noted before upon the Equinoctial count 1 hour 36 min. sooner (that is towards our 12 a Clock) and find that hour or point of time in the Parallel of ♑, and there you shall have a second point of the Horizon: These with the Gnomon make the three requisite points to draw or project the Horizon: And this is the easiest way; but more ways might be found to perform the same thing, yet these may very well suffice.

CHAP. VI.

I. *The Use of all the Lines of the Furniture.*

THE Point of the *Gnomon*'s Shadow sheweth (among the *Equator* and Parallels thereto.) 1. The Sun's Parallel of Declination. 2. Parallel of the days length. 3. The Sign wherein the Sun is—Amongst the *Almicanters* it sheweth; 4. How high the Sun is above the Horizon. 5. What Proportion the shadow of any upright thing, cast upon an Horizontal Flat, beareth to the upright Body—Amongst the *Azimuths* it sheweth. 6. What *Azimuth* the Sun is in. 7. What Point of the Compass the Sun is on——Amongst the projected Eclipticks it shews. 8. What Sign is ascending above the Horizon, or descending. 9. What Sign is Culminating——Among the hours of other Countries Account, it shews 10. The hours of ☉ Rising.

11. Or

11. Or from and to ☉ ſetting. 12. It ſhews alſo the Planetary hours. 13. What houſe the ☉ is in. 14. And principally the hour of the Day. And what elſe may be deduced out of theſe.

II. *Of the Commodities of theſe Projective Ways.*

Leſs coſt beſtowed; No Inquiſition after the ſite of the Superficies in reſpect of Declination or Inclination; Not material whether it be upon one, or more Superficies together; Nor whether the Deſcription be drawn upon a plain Superficies, or curved one, or more; Not material how thoſe more Superficies do ſtand, whether contiguous, or remote, one to another; The tediouſneſs of an *Axis* both making and ſetting avoided; The Inſertion of the Furniture infinitely bettered and eaſed; No trouble in the obſervation of Caſes comparable to the other;—The greateſt trouble is the finding out the Sun's *Azimuth*, which yet may be avoided, if an Obſervation be made juſt in the Meridian.

No trouble by reaſon of inconveniences that fall out, when the Stile hath but ſmall Elevation, and the Dial without a Center, the other ways are very troubleſome.— The way that all men hitherto went, was firſt to make the Dial, then to ſet the *Gnomon*; But this is quite contrary and much better becauſe the trouble of ſetting the *Gnomon*, is much harder than fitting the hours to it: For here the *Gnomon* is firſt ſet, and then the hours fitted to it; Caſes in Declination, and Reclination avoided; In great Recliners it is hard by other ways to pitch the Work true, for a ſmall error in the Horizontal Line, may cauſe a degree or two in the Vertical, upon which all depends; The very plaining of the Superficies (if no thing elſe were to be done) is more troubleſome, than all this work of finiſhing the Dial.

POSTSCRIPT.

IT was my intent, in this Place, to have inſerted a Figure in Perſpective, repreſenting the inſide of a Room, with ſeveral *Hour-lines*, *Tropicks*, *Azimuths*, *Almicanters*, and other Lines of the *Furniture* of *Sun-dials* drawn upon the *Walls*, *Window-boards* and *Jambs*, and other various *Plains* which the inſides of almoſt all Rooms are incumbered with, and therein ſeveral *Cupits* or ſmall *Figures* repreſenting the *Actings* of thoſe things, namelly, the extending and projecting of *Lines*, hanging of *Perpendicular Threads*, and other performances in this *Tractate* required to be done and there only verbally directed; but being (my ſelf) no Deſigner or Draught's-man, I could not meet with any perſon that with convenience (to my ſatisfaction) could hit my intention in that kind; but that was my intent to have done both in this of *Projective* and the next Tractate of *Reflective Dialling*: but being thus diſappointed of my intentions in this kind, I ſhall give you a ſhort account of ſome Dials, made after theſe *Projective* ways.

Firſt, If in the Glaſs-window of any Room, one Pain or Quarry of Glaſs be darkned, and a hole about a quarter of an inch Diameter about the middle thereof, the Sun ſhining upon the Window will, thro' that hole, caſt a bright Spot of Light into the Room, which as the Sun in his motion paſſeth by the Window, the Spot of Light will be alſo removed from place to place, ſometimes upon the Window-boards, ſometimes upon the Jaumbs, ſometimes upon the

the Sides, and ſometimes upon the Floor of the *R*oom.---If ſuch a Hole ſhould be ſuppoſed to be the *Gnodus* or Point of the top of the Perpendicular Stile of any Dial, I ſay from it the Hour-lines of a Sun-dial or of ſeveral Dials (for every ſide or part of the Room is a different Plain) may be made about the Room, If,

1. Horizontally you apply an Horizontal Dial to the Hole in the Glaſs-window, and extend a third Horizontally alſo from that Hole over every Hour-line (or half and quarter Hour-line) till it touch the Sides, Doors, Windows, Jambs, or other Objects or Impediments (ſtanding in the way) about the Room: Then,

2. The Twelve a-clock Hour-line being both an *Hour-line* and an *Azimuth* alſo, you may (by a Perpendicular Thread or Threads,) transfer the ſame to the Cieling or Floor of your Room, or to which of them will beſt ſerve your Turn, and ſometime there may be occaſion for both: Then,

3. In this Meridian Line find another Point, from which, a Line or Thread extended to the Hole in the Window may repreſent either the Direct (or Reverted) *Axis* of the World, and unto that Point or Points all the Hour-lines which you draw in that Room will have reſpect unto (or be in the ſame Plain with) this *Axis*: And therefore,

4. If you fix a Thread in one or both of theſe Points (or Poles rather) and extend that String by the Side of another String extending from the Hole over any Hour-line or Point found on the ſide of the Room as before, that moveable String being gently moved by the Side of the Horizontal String ſhall trace out (upon all Objects that it meets withal) the Hour-line which the extended Horizontal String doth repreſent.

Secondly, If a Spot, or the Sign of the Sun (or what ever elſe you fancy) be made or painted upon any Pain of Glaſs in a Window; And on the outſide of the Window ſome Horizontal Border (Semicircular, or of any other form) be made of Wood or Wire; and a Meridian Line found which ſhall paſs thro' that Hole, another Point of the *Axis* may be found, in which Lines extended by the Horizontal Lines extended from the Hole to the Horizontal Points in the Border, thoſe Hour-lines may be projected to the Monions of the Windows, and there faſtned, as alſo to the Horizontal Border, and theſe ſhall be true Hour-lines, whoſe Names or Numbers being ſet in a Border of Paper paſted (or painted) about the Pain of the Glaſs-window, where the Spot is: Then the Strings without (which are the Hour-lines) when the Sun ſhineth, with all of them, caſt their Shadow upon the Pain of Glaſs, and the Shadow of that which toucheth (or is neareſt to) the Spot made or painted in the Window gives the hour of the day.

Infinite are the Varieties of this kind, of which you ſhall have hints of many at the end of this Book, in the Deſcription of the *Pyramidical Body of Dials*: And ſo I ſhall conclude this *Tractate*, giving you here only the Figure of an Horizontal Dial for the Latitude of *London*, with its Furniture.

The End of the Tenth TRACTATE.

REFLECTIVE DIALLING, OR, OF DIALS by REFLECTION.

SHEWING,

How to Reflect the Sun Beams, and to Describe *Hour-Lines*, and other *Furniture* for *Dials*, upon such *Plains* upon which the Direct *Beams* of the *Sun* can never shine; and that several ways, the *Glass* casting the Reflection, being placed either Parallel to the *Horizon*, or Oblique unto it: And without any regard had to the Situation of the Object upon which the Reflection is made, *i. e.* whether it be Plain or Curved, one or more, contiguous or separate, *&c.*

The Eleventh TRACTATE.

CHAP. I.

Notes and Observations preceding Reflected Dials.

THESE Glasses, for their Fashion, are best to be Flat and Round (though that be not necessary) and the quantity of it such as will reflect the Sun Beams, when they are at a small Elevation, which therefore cannot be so easily determined, because Glasses are of several thicknesses; and the thicker it is, the broader it will be required to be; the thinner the narrower; and reflecting the more singly and truly. The standing of the Glass may be either Flatly Horizontally, or otherwise Reclining or Inclining, according as the place where it is pitched will require it should reflect, upwards, downwards, or sideways; or as the skilful Artist shall think fit, to give evidence of his knowledge and Dexterity in this kind. The Superficies may be any thing that is capable of receiving Light and Shadow; it needs not be a Plain, as is required in other Authors, neither needs it be one Single Superficies, but it may be turned or distorted any way; it may be a multitude of mixt Superficies, of any fashion or number whatsoever. To make the

Projection, it is required that there be room convenient; and because these are made for the most part in Windows, where the reflection of Light may be best made in the shady places of the inner parts of the Rooms; it will be required that liberty be allowed to work without the Window also. It is not absolutely necessary that the Glass should be flat, it may be of another Form, if you desire to have it so, but then your Hours cannot be so easily projected, because they will not be strait but crooked Lines upon a plain Superficies, and the trouble augmented to find so many several points, as will be requisite to the drawing of such bending Lines. But because most Glasses are flat, and it will be harder to procure one that is not so, than one that is; and because also, any that is ingenious this way, will of himself (though some things are here also delivered, which will be Directions enough) be able to find out the manner of projecting from an irregular Glass, after he is possessed with this that is here in the first place delivered; I will only shew how to do it, to a flat Glass, in what Situation soever it stands, because by it any of the other Forms will be understood. If any will reflect upon Water and other Liquors, it is apparent that they will ever lie Horizontal; and so the way to do that will be the same with the Horizontal Glass, which comes after in its due place.

CHAP. II.

Of Reflected Dialls.

For Glasses there are most varieties of Situations; Liquors lying all Horizontally flat without any Inclination at all.

Reflection is best made by a piece of Looking-glass, which is so much the better, by how much it is thinner; for the thickness of it causeth a double ray of Light to be reflected, and requireth a greater elevation of the Sun Beams than a thin one doth: it must be about Seven times the thickness in breadth; and because Glass reflects from the upper and neather Superficies, and so makes two spots, colour the lower Superficies therefore with Oyl Colour, or (which is better) rub or grind it, on a rough Brick, Tyle, or Grind-stone, and it will make but one spot. Now a Glass may be placed either Horizontally or Obliquely; and the inner Rooms of Houses (for which this way is most accomodate) may fall out to be either flat or turned, both on the Cieling and Walls. In all these Varieties it will be esteemed none of the easiest works to protract true Hours; and what others have written in this kind, is only for to draw Hour-Lines to a Glass placed truly Horizontally, reflecting upon a flat Cieling, which is likewise *in æquilibrio* with the Horizon; which very particular I will here also shew how to perform in a much more easie way than hath yet been practised, after I have first delivered in general (amongst many) Three several Ways.

CHAP.

CHAP. III.

How to project Hours *from a* Glaſs, *however it ſtands upon any* Superficies *whatſoever, or how manifold ſoever it be.*

SECT. I. *The Firſt General Way.*

YOU muſt ſtretch an Horizontal Thread, between the Glaſs and the Sun, at any reaſonable diſtance from the Glaſs, and *in æquilibrio* with it; upon this Glaſs and upon the Horizontal Thread (by help of a proper Thread) project the Sun or ſhadow of the Thread, juſt as was before taught in making a Dial with an Axis; and according to thoſe Precepts (ſuppoſing the Glaſs to be as the point there aſſigned) make up here (in the ſame manner as is there taught) the firſt of theſe Precepts, ſo ſhall you find the Pole of the World, as at the end of the Eighth Precept is declared. Theſe things being thus prepared, you are to begin with your Reflections in this order and manner. First General Way for Flat Glaſſes.

1. Reflect the true Pole of the World, before found, upon ſome Object, which is done by looking into the Glaſs, till you ſee the fore-named true Pole. And to the end you may the ſooner diſcover it, you may find this or the like helps: Stretch a Thread, or draw your Finger from the Glaſs to the true Pole; which Thread or drawing of your Finger (if you follow the ſhadow all along as it appears in the Glaſs) will bring you to the ſight of the true Pole; and this ſame courſe muſt be uſed in all other Reflections, which may ſerve as a general Admonition once for all, in all the reſt of the work. And when you have diſcovered it in the Glaſs, place ſome mark then at your Eye (ſuppoſe ſome Wire or Thread fixed at one end, the other end at liberty in your Hand, the Thread having a ſlipping Knot upon it. This Thread and moveable Knot may be removed to any poſture, and ſerves as a Mark or Point; ſo that looking or laying the ſame Point upon the Glaſs, with your Eye you may alſo juſtly ſee the true Pole or Mark of it in the Glaſs) then may you extend a Thread from the Glaſs to this Point or Knot, up to the top of the Houſe (or to the Walls or Floors according as things are placed) and ſo make a point there, which may be called the Reflected Pole. (Or the former Point, if it ſtand firm, may as well ſerve to ſupply the uſe of the Reflected Pole.) To this Reflected Pole fix a Thread, which will perform all the Projection that hereafter followeth. This Thread, for diſtinction, may be called the Reflecting Thread. This may be called the way to diſcover.

If you will take pains to ſtretch Threads to every Hours Point, and to project the Parallels thereinto by the Semi-Circle, you may reflect the Knots, and ſo reflect the Parallels by your Eye.

2. All

2. All the Hours will be projected by these helps very easily; for having by your Eye discovered in the Glass any of your Hour Points fixed in the Horizontal Thread (your Eye being at a good distance from the Glass) take the Reflecting Thread, and interpose it between your Eye and the Glass (the further off it the truer) so as that the Eye may repose the Thread upon the Hour Point of the Horizontal Line appearing in the Glass; and the Thread in this Position fixed, will give the Hours reflected upon any Superficies whatsoever it be that stand in the way.

3. Having fixed the Reflecting Thread, as before, fix (or let one hold) another Thread (a Projecting Thread) to the Glass, and taking the other end of it your self, apply it all along the side of the Reflecting Thread, drawing it out at full length, till (namely) it reach to the Top, or Walls, or Floor of the Room; so shall you prick out the Tract of the Course of the Hour Line upon all Superficies, as lie in the way, where through you draw out your Projecting Thread; and if the Superficies, be flat, you need not make above two Points upon one Superficies, and so draw a strait Line through those two Points. The same work is to be repeated every Hour particularly, and in the self same manner; so that I shall not need to spend more words.

And Note, That in all Projections (Direct as well as Reflected) if you have the Gnomon, or Point, or Glass (but the Glass must be flat) and any one part of an Hour Line drawn upon the Superficies, you may, after the Dial is finished, transfer that Hour to any Superficies beside, by stretching one Thread from the Apex of the Gnomon to any Point of that Hour Line that is drawn; and then by stretching another Thread from the same Line, by the sides of the first Thread, till it touch the Superficies, upon which you would have it Projected, and into as many Points as shall be required, through which the Hour-Lines may be described.

A Note concerning Drawing of Hour Lines to be Reflected upon from Concave or Convex Glasses.

This is the general way to Reflect Hours from all Positions of a flat Glass to all kind of Superficies.

If the Glass be not Flat, but Convex or Concave, you must extend a Thread from the Reflected Pole to the Points or Hours in the Horizontal Thread, and there fix it; then discover in the Glass several Points of the same Thread, making standing Marks (one at a time) for the several Points and from the Glass through those standing Marks (one to be done before you go about the other) extend a Thread to the Roof, or Wall, or Floor; this extended Thread shall give one Point for the intended Hour. Thus you are to do for other Points of the same Hour, by which means you shall find several Points for one Hour, through which Points you must draw a Line, which will not be strait, because the Glass is not Flat. In the same manner do for all the Hours.

SECT.

SECT. II.

The Second general Way is this, and it concerns only Flat-Glasses.

HAving stretched an Horizontal Thread, and fixed Hour Points upon it, as in the former way, you must find the Glasses Zenith Point, which is easily done, if you look till you see your own Eye Reflected in the midst of it; for if you there set a standing Mark (as was before shewed) and by another Thread extended from the Glass to that Mark, continue the Extension of it until you meet with some Object (*viz.* Walls, Cieling, or Floor,) this Thread will there give you the Glasses Zenith Point; from which Point to the Glass a Thread must be fixed, representing the Glasses Zenith Line. Second general Way for Flat Glasses.

Now because Angles of Incidence and Reflection, are the same in quantity from the Zenith Line, but cast to the contrary Coast and because likewise the Lines of Incidence and Reflection are both in the same Superficies with the Zenith Line (that is to say, the Superficies wherein they three are, is ever proper to the Superficies of the Glass.) If therefore you extend Threads, one from the Glass, to a Knot in the Horizontal Thread, and another second Thread from the Glass also; but on the other side of the Glasses Zenith Line (which second Thread must lie in the same Superficies with the first Thread and Zenith Line, which when it doth so, your Eye will discern, for in this case all the Threads will lie to view, one upon another) making an Angle with the Zenith Line on the contrary side, equal to the Angle made by the first Thread with the Zenith Line. How to make this Angle equal, I leave here to be described hereafter.

Let the first Point Reflected from the Horizontal Thread, be the Meridian or 12; the Thread then so disposed (as before) will give one Point of the Meridian, upon the Roof or Wall of the House. And by the Zenith Line or Thread of the Glass, by reposing of it with your Eye upon this Meridian Point, you may draw the Reflected Meridian Line; then consider whereabout the true Pole of the World, which is elevated above the Glass, is and elevate it by the Semi-Circle in the true (not Reflected) Meridian, and cast it upon some Object (Cieling or Wall, *&c.*) and from the Glass to it extend a Thread, which is the true Axis of the World. This must now be Reflected, by making another Thread to pass from the Glass, on the contrary side of the Zenith Line, but making equal Angles from it with the first. And to do this, and to judge when it is contrary, is before shewed in the Projecting the Points of the Horizontal Line. This Thread is to be fixed, and represents the true Axis, and is therefore to be called, *The Reflected Axis of the World.* So then all the work will be now, to Reflect the several Points of the Hours upon the Horizontal Line, unto the Roof or Walls, or what Object soever (Flat or not Flat) stands in the way; and then by this Reflected Axis to Project them, by those Reflected Points, all over all the Objects that stand in the way. This is the Second General Way, which cannot in all particulars be applied to curved Glasses, because a curved Glass cannot be counted as one Plain, and cannot have one Zenith Line.

SECT. III.

The Third General Way is only for Flat Glasses.

Third General Way for Flat Glasses. 1. YOur Glass being set, and the Sun shining, observe the spot of Light Reflected, and make a Mark at it; At the same instant take the Sun's Altitude, and inquire what Azimuth the Sun then had.

2. You are to make a Reflected Horizontal Line thus; set any two Points *in equilibrio* with the Glass, Reflect those two Points in the same manner as was shewed before, and make two standing Marks, as was before declared; then through those two standing marks extend a Thread; this Thread (though nothing at all Parallel to the Horizon) shall represent the Horizontal Line, and must be fixed, and called, *The Reflected Horizontal Line.* This may be turned or continued sideways, upwards or downwards, as occasion shall offer it self, by turning a Thread from the ends of it, in such wise that the casting (with your Eye) the first fixed Thread, upon (or unto) the Glass, the continuation, or returning Thread, may be seen all one with the first Thread, and so lie in the same Superficies with the first Thread and the Glass. All these Threads are to be accounted for the Reflected Horizontal Line.

3. Your own Zenith or Nadir Point must be Projected, which is done by setting some Marks or Points, perpendicularly over or under the Glass; and removing your Eye till you can see the same in the Glass: then when you see it, set a standing Mark, so shall a Thread extend from the Glass to this standing Mark, and so till it meet with some Object, represent the Zenith or Nadir Line (not of the Glass but) of the Horizon, to which end let the Thread be there for a while fixed.

4. By reposing this Thread upon the spot of Light before found (which respects the Azimuth wherein the Sun was at the time of Observation) you may project the Sun's Azimuth into the Reflected Horizontal Line, where you are to tie a Mark; for this guides all the Work that follows.

5. Next consider whether the Azimuth were East or West, and consequently, on which side of it the Meridian will fall; which being known you must upon this Reflected Horizontal Line protract the said Azimuth in the same manner that is used in the former way, from that Reflected Horizontal Line into the Past-board; only you must observe to do some things (though the same in substance, yet) different in a peculiar manner, as thus: Upon a Past-board (or any other Flat) being held to the Glass, as the Apex of a Gnomon, and staid so by resting upon some Substentacle, that (though it be taken away, yet again) it may be applied to the self same posture: I say upon a Past-board fitted to the purpose, and applied to the Center of the Glass (being taken here as the Center of an Horizontal Dial) and directed also towards the Reflected Horizontal Line, that it may fall into the same Plain; stretch out a Thread from the said Center to the Point of the Azimuth noted upon the Horizontal Reflected Line, and note the Line that the Thread makes upon the Past-board, for the same Line represents the afore-said Azimuth.

6. For this Azimuth, observing the true coast of Reflection, set off the

the Meridian, and so to describe upon Past-board an Horizontal Dial (remembring how to number your Hours by considering unto what Coast the Reflection will carry them) and putting your Past-board upon its former Situation, with a Thread from the Glass or Center, project all the Hours from the Past-board to the Reflected Horizontal Line; and tie Marks at each of them severally.

7. You are then to Reflect the Pole, and to fix a Reflected Axis in this manner: First, Reflect the Zenith or Nadir Point, and make a standing Mark at it; then extend a Thread so, as that through the length of it you may see the Point of 12 in the Horizontal Line, the Reflected Zenith and Nadir Point, and the Glass, all three together, so shall you, by that means, lay this Thread in the Planities of the Meridian. Now in the Meridian lie the Poles of the World, distant from the Horizontal Line (that distance being counted in the Meridian Superficies) so much as the Elevation of the Pole, or the Latitude of the Place, or the Supplement of the Latitude cometh to. Now whether to choose the Latitude or the Supplement thereof, the disposition of the Work will be ready to shew you. After this then apply a Past-board to the Glass, and set it always directly towards that Thread in the Plain of the Meridian, and let it always rest upon some stay, that though it be taken away, yet it may be again placed in the former true posture. Then from the Glass to 12 upon the Horizontal Line, extend a Thread, and draw upon the Past-board the Line that the Thread sheweth; and upon the same Past-board from that Line so drawn, and from the Glass, as a Center, or place the of it on the Past-board, protract an Angle of you Latitude, or the Supplement of it, that way that the Reflected Pole would happen, and applying your Past-board to its old place again, by a Thread from the Glass extending along that Line on the Past-board and fixed, you have the Reflected Axis.

8. Having fixed this Reflected Axis, by it and the Points upon the Horizontal Reflected Thread, you may project the Hour Lines upon any Object (flat or curved) whatsoever it be, and after draw them, and distinguish them as before hath been shewed.

For further Observation herein, Note, That it falls out oftentimes that Windows are so disposed, that no Axis can be fastned to project withal; and the Rooffs likewise so uneven, that a true Horizontal cannot be protracted: In such cases, if the Glass lie flat, you may help your self in this manner: Extend an Horizontal Thread in the Air, lying level with the Glass; upon this Thread project the Points of an Horizontal Dial; likewise stretch another Thread in the Air, directly East and West, parallel to the Horizon, elevated above the Meridian at an Angle from the Glass $38\frac{1}{2}$, equal to the Equinoctial's Altitude; and upon this Thread also project Hour Points by an equal Circle or Past-board, *&c.* Now if you extend Threads from the Center of the Glass to the Horizontal Hours, and from those extended Threads, do extend others to the equal Points upon the Roof, you shall make points enough through which to draw the Hours.

CHAP.

CHAP. IV.

How, to a Gloſs laid in the Window, and placed truly Horizontal, to Draw Hours upon a ieling that is alſo truly Horizontal, and Flat, not Curved.

THE following way of the next Chapter is projective: This is for the moſt part Lineary, and ſuitable to other Draughts. This is alſo more particular, tied to the Cieling, and to that alſo as flat only and ſingle, not any way curved or multiplied. The other following will be for all kinds and numbers of Superficies in general. This more frequent and more eaſie alſo, that more ſeldom happening and more difficult.

This is branched into two Caſes, that is more generally delivered in one way; in both which this is common, namely, Firſt, Obſerve a Spot of the Sun's Light made upon the Cieling, and to make a mark at it, and take the Sun's Altitude at the ſame inſtant, and inquire what Azimuth the Sun then had.

Theſe things ſo prepared, you are likewiſe to find a Meridian Line, to which end you muſt alſo find the Zenith Point of the Glaſs upon the Cieling in this manner: Hold a Perpendicular Thread to the Cieling, in ſuch place that through it you may at once ſee both the Mark made for the ſpot of Light obſerved, and alſo the Center of the Glaſs, then protract that Line (blindly) upon the Cieling, which the Thread ſo hanging ſeems to make upon it; this Line ſo drawn repreſents the Sun's Azimuth at the time of Obſervation. Again, Hold up to the Cieling, in any other place of it, the ſame proper Thread, and remove your Eye till you ſee (through the hanging Thread) the Center of the Glaſs, and (your Eye there ſtanding) obſerve where the ſame Thread cuts through the Azimuth Line before drawn; at the apparent interſection make a Mark, for that is the Zenith of the Glaſs, or the Point that is juſt over it perpendicular. Upon this Point, now being taken as a Center, deſcribe a piece of a Circle from the Azimuth Line, and ſet off (upon it) the diſtance of the Meridian from the Azimuth, keeping the true Coaſt that it ſhould have, which your own Judgment will tell you well enough; then from the Center to this diſtance, a Line drawn, will give you the Meridian Line. Having thus found a Meridian Line or Line of 12, the reſt of the Work will branch it ſelf into two Forms, according as the Window ſhall look, towards either South or North.

SECT. I.

If it be a Window, whoſe Aſpect is towards the South.

FRom the Glaſs elevate your Semi-Circle towards the North part of the Meridian which you have Drawn upon the Cieling; I ſay elevate your Semi-Circle directly from the Glaſs to the Meridian, unto the Altitude

Altitude of your Equinoctial, and where the Ruler of your Semi-Circle points (which may be found by a Thread apply'd to, and extended along, the same Ruler, till it meet with the Plain or Cieling) into the Meridian, there make a Point; through this Point draw an infinite Line, perpendicular to the Line of 12 or Meridian; this Line represents the Equator, upon which you are next to insert the Hour Points in this manner: Take with a pair of Compasses the Distance between the Glasses Center and this Point of Intersection, between the Meridian and Equinoctial Lines, the same Distance you must account as a Radius, and is therefore to be divided into 1000, or more, Decimal Parts, as your Decimal Scales use to be. Then out of this Scale, and by help of a Natural Canon, take the Tangents of each Hour, or 15 deg. *viz.* 15, 30, 45, 60, 75, and prick them down upon the Equinoctial Line on both sides the Line of 12, so many as the Room will receive, so shall you have 5 Points on each side of the Meridian (or so many of them as the Room will give way for,) through which all the Hours are to pass; and so if the Center of the Dial, or the common Point of their concourse were within the Room, it were a very easie business to draw all the Hours from those Points to that Center and the Six a clock also through the same Center, perpendicular to the Line of 12. But because the Centers of these Southerly Dials do most commonly fall without the Room, therefore this way cannot be used. The best way therefore that I can judge of is this, You must have an Horizontal Dial Calculated for your Latitude, then supposing the space betwixt 12 and 11, or 1, the next Hours on either side to be 11 deg. 51 min. you may take the Complement of that space, which is 78 deg. 09 min. and upon the Points of the Hours next to 12, as upon two Centers describe two Arches of Circles, and protract the Angle of 78 deg. 9 min. from the Equinoctial Line, so shall Lines protracted at those Angles from the Equinoctial Line, be the true Hour Lines required. For if the Angle between 12, and the next Hour be 11 deg. 51 min. and the Angle between the Equator and Meridian be a right Angle, then must the Angle betwixt the Hour and the contingent Line be the Complement of 11 deg. 51 min. that is 78 deg. 09 min. Thus you may do for all the rest of the Hours till you come to 6. For the 6 a clock Line you must know, that it is to be drawn Parallel to the Equinoctial Line, and to be distant from it, as much as the Co-secant of the Latitude taken to the fore-named Radius, or decimal Scale will extend unto.

For the other Hour Lines that are further remote from 12 than 6 is, it will be best to do thus; draw a line in any place, but perpend. to the Line of 6, and observe at what Distance and Angles the Hours already drawn do stand from 6, and what Angles they make with the perpendicular last drawn. Set the same distance upon the Line from 6, and at those Points protract the same Angle to the Line last drawn, so shall the Lines protracted be the true Hours required.

But if in this case your Equinoctial Line is not long enough to hold all the five Hour Points between 12 and 6, you may help your self thus, Prick down as many of them as you can from 12, three at the least, then draw a Line Parallel to the Equator Line, so that the length of it betwixt 12 and any Hour, may be ½ or ¼, or some such like part of the length of the Equator intercepted between 12 and the same

Hour, that the work may be the more eaſily proportioned; when this is done, you may upon this laſt Line ſet off from 12, or, of the Tangents before-mentioned, which will give the Points in the ſaid Line, through which the Hours muſt paſs; and becauſe the Line is parallel to the Equator, therefore at thoſe Points you muſt make the ſame Angles with this new drawn Line, that the ſame Hour would have made with the Equator, and therefore they muſt be protracted in the ſame manner. And if you would caſt the Hours from the Cieling to the Walls, you may do it by the general way ſet down in the fore-going Precepts to transfer any Hour by the Apex of the Gnomon, any part of that Hour being given or drawn.

You may turn the Secant of your Latitude at any other Hour, as 4, and divide it into the Tang. 30. Or you may at the third Hour Point from 12 in the Equinoctial, turn up a Perpend. to the Equin. or a Parallel to 12, and make that Line to be in length equal to the Co-ſecant of the Latitude taken out of the former Decimal Scale or Radius. If now at the end of this length you draw a Line Parallel to the Equinoctial, the ſame will be the Line of 6. Then further, taking the Co-ſecant of the Latitude as a Radius, or Decimal Scale, ſet upon it (as a Radius) from the Point of 6 the Tangents of 15, 30, and 45, that is the Tangents of 1, 2, 3, Hours; the third Hour Point being at the meeting of the Equator, and this Point, or the whole length of the Line, and (which I ſhould have ſaid before) draw this Line quite beyond, as far as the Cieling will ſuffer, and from the Point of 6, both ways, or on both ſides of it, ſet on the Tangents as before; ſo have you the Points through which all the Hours muſt paſs. Then if it be known at what Angles to this Line the Hours do lie, it will be eaſie to protract ſuch Angles upon the fore-placed Points, and accordingly to draw the Hour Lines. Now the Angles that each Hour Line makes, with this Line laſt drawn, are the ſame that they make with the Line of 12, and accordingly muſt be protracted.

SECT. II.

If it be a Window looking towards the North.

HAving found a Meridian Line, as is ſhewed before; from the Glaſſes Center upwards into the Meridian Line, elevate your Semi-Circle, according to the Latitude of your place, and obſerve (by a Thread joyned to the Ruler of the Semi-Circle, if need require) where the Ruler of the Semi-Circle Points out the ſame Latitude, there make a Point, for that is the Center of your Dial, which is nothing but a plain Horizontal Dial. If you deſcribe a Circle upon the Center, and likewiſe out of that Center erect a Pependicular to the Meridian, you are fitted to perform your work; for you have no more to do but to ſet off either from the Hours of 6 or 12 (which you like beſt) all the other Hours, according to their ſpaces, in an Horizontal Dial from 6 or 12; and ſo this caſe proves eaſier than the former did.

CHAP.

CHAP. V.

How by this manner of Work upon a Flat Window *that is truly Horizontal, and to a Point ſet up, as the Point of a Gnomon, may Hours be protracted to a direct Shadow : Thus,*

OBSERVE the ſhadow of the Point, mark it, take the Sun's Altitude at the ſame inſtant, and require the Azimuth ; then with a Perpendicular Thread project the mark of the Azimuth, upon the Point of the Gnomon, and draw that ſhadow or tract of the Thread made upon the Window-board, which Line will be the Azimuth. Again, Hold up your Perpendicular Thread, and Through it view the Point of the Gnomon, and at the very inſtant (your Eye and Thread being both immoveable) ſee alſo where the Thread appears to cut the Azimuth before drawn, and mark that point of interſection ; upon that Point, as a Center, deſcribe a Circle, and upon the ſame Circle (from the Azimuth toward the true Coaſt) ſet off your Meridian and draw it. Then,

SECT. I.

If it be a Window looking towards the South.

FROM the Point of the Gnomon down to the Meridian, let fall your Semi-Circle, ſo much as the Complement of the Latitude comes to, and mark the Point which the Ruler of your Semi-Circle then makes upon the Meridian: Perpendicular to the Meridian, in this Point, draw the Equinoctial Line, and then finiſh all your Work, as is taught before in Cieling Dials ; for it is the ſame quite through, without any manner of difference at all ; and ſo there needs no more to be ſaid of it.

SECT. II.

If the Window look towards the North.

FIND out the Meridian, as you did before, then from the Point of your Gnomon, depreſs your Semi-Circle, into, or upon, the Meridian, ſo much as your Latitude is, and note the Point in the Meridian, that the Ruler pointeth out, for that is the Center of the Dial ; from which Center a perpendicular to the Meridian, is the Line of 6 ; and from 6 and that Center you may protract all the Hours, as before in Cieling Dials, that look towards the North.

CHAP.

CHAP. VI.

How from a Glaſs *Horizontally placed (or from* Water *or other* Liquors) *to Reflect Hours upon any Superficies Flat or Curved, one or more.*

All the Furniture of Dials may be put into Horizontal Flat Glaſſes, by expreſſing upon the Hour Lines (with your Semi-Circle) ſuch Altitudes as are true, and that above (not below) the Glaſs or Horizon.

THIS is for Reflected Dials within a Room, and is not yet limited to a plain Superficies, but in general to all, Flat or Curved, lying Horizontal or ſtanding Upright, or elſe Leaning. It is general, in reſpect of the Superficies, whereunto the Deſcription is to be made, but particular in reſpect of the poſture of the Glaſs, for that is here required that it ſhould be Horizontal. Now to place it Horizontal, do thus, Lay it into a little Board, flat and even with the Board, and either make it faſt, by forcing it into the Board (the place of it being ſtrait and juſt fit) or elſe overlay it with a Plate of Lead beaten very thin, but beſure it lie true to the flat of the Board; then with a ſmall Level lay the Board truly Flat or Horizontal, which will be done without any great difficulty, which is to lie for the moſt part in the Window.

1. The Glaſs being laid, obſerve the Spot of Light that the Sun caſts, and make a mark at it.

2. And immediately obſerve the Sun's Altitude, and find the Azimuth.

3. Then extend an Horizontal Thread in the ſame Level with the Glaſs, but within the Room.

4. Afterwards project the Azimuth into the Horizontal Thread, by holding up a Perpendicular Thread in ſuch a place, that though it hang at liberty, you may at once diſcern both the mark of the Spot of Light, and the Glaſs likewiſe; and then obſerve where the Perpendicular Thread ſeems to cut the Horizontal Thread; at that apparent interſection tie a ſhort Thread for a mark of the Azimuth.

5. Apply a Paſt-board to the Glaſs, and ſo that it may be ſtaid upon ſome reſt, that after it is taken away it may be reſtored to the firſt poſture without impeachment: Let it be alſo held Horizontally, ſo as that it may have full Relation to the Horizontal Thread.

6. At the Glaſſes Center make a Point for a Center upon the Paſt-board, and extending a Thread from the Center of the Paſt-board to the mark of the Azimuth upon the Horizontal Thread, draw upon the Paſt-board that Line which the Thread ſo extended figures out thereon. Afterwards, unto the ſame Azimuth, upon the Paſt-board, draw a Meridian, and to it an Horizontal Dial, and applying the Paſt-board to its firſt Situation, project the Hours thereon, unto the Horizontal Thread, and the Knots; all which is done in the Room.

7. Then project the Meridian (by a perpendicular Thread, covering, in appearance, both the Knot of 12 and the Glaſs) unto the contrary Coaſt to that wherein the Pole is elevated (above the Horizon) that is to ſay in our Northern Climats you muſt project the Meridian Southwards from the Glaſs, becauſe the North Pole is elevated. And in the Meridian, elevate your Semi-Circle from the Glaſs Southwards, till it riſe up to your Latitude; ſo ſhall the Ruler of the Semi-Circle point out (upon ſome Object ſet to receive it) the North Pole Reflected

Or

Or elſe if that be not convenient (becauſe in Windows or ſuch like places that ſtand towards the South, the North Pole will be without the Room, and ſo the Axis above the Glaſs extended towards that Pole will be without alſo) you may in ſuch caſes find out the oppoſite Pole to it, that is to ſay, the Pole which the former reflected Axis being extended through the Glaſſes, and below it, would ſign out, and that may be effected in this manner:

Project the Meridian Line towards the Pole that is elevated, that is with us towards the North Pole, and then (becauſe the North Pole is elevated by Reflection towards the South, ſo, by the ſame reaſon the South Pole muſt be depreſſed towards the North) with the Ruler of your Semi-Circle, directed even with the Center of the Glaſs, expreſs or project your Latitude downwards (but towards the North) ſo ſhall the Ruler of the Semi-Circle point out the Reflected South Pole in the Meridian. Now whether you will or can (moſt conveniently) uſe the reflected North Pole above the Glaſs, or the reflected South Pole below it, you are to take your choice, for both the one and the other of them do repreſent the reflected Axis of the World.

8. By this reflected Axis, and the Hour Points ſigned out upon the Horizontal Thread, you may eaſily project the reflected Hours, in the ſame manner that hath been heretofore declared upon any kind of Superficies, one, or more, what ever they be that ſtand in the way.

CHAP. I.

How to make a Dial *to a Flat* Glaſs *laid aſlope, reflecting the Hours all obliquely, and upon any kind of Cieling, whether Flat or Curved, or mixt of both,* &c. *If the Window wherein it is placed look towards the* South.

ALthough ſomewhat hath been ſaid hereof before, yet this being in ſome particulars different, it ſhall be ſet down in ſeveral by it ſelf.

SECT. I.

Of ſetting the Glaſs, *and fitting it for the intended uſe.*

IF it be a piece of Looking-glaſs foiled, then the Work of the Dial will be the moſt viſible, and ſo more expedite; but then it will reflect two ſpots of Light at the leaſt, the darkeſt whereof coming from the upper Superficies, will be the Spot that the Dial will anſwer unto; but if the Foil be rubbed off, and the back-ſide (inſtead of Foiling) be covered over with thick Oyl Colour, or rubbed on a Brick, *&c.* then will it reflect only the dark Spot from the upper Superficies of the Glaſs, and the light Spot (which in the other came from the Whiteneſs and Politneſs of the Foil) will (in this) be utterly loſt. This will be the

truer way to go, but the more obſcure for Reflection, both in making and uſing of the Dial. Which ſoever of the two Glaſſes you will uſe, let it be of an indifferent large Diameter (about ¾ of an inch or more) that the Reflection may be the more facile, as hereafter will be ſhewed. Let it be inlaid into a piece of Lead or elſe Wood, ſuch as the heat of the Sun Beams may not alter; and there fixed with hard Wax, or ſuch like glutinous matter; then place it aſlope in ſuch conveniency for Reflection as you ſhall judge fitteſt, namely, ſo as the work may be (moſt of it at leaſt) caſt upon the top and ſides of the Room, and as little as may be upon the Floor. And if the Stool of the Window wherein you fix it be broad, then let it not ſtand upon the Stool of the Window, but above it, at ſome reaſonable diſtance, leaſt by the ſame Stool you, perchance, be hindered in the Reflection. Upon the middle of your Glaſs, as near as you can gueſs, make a ſmall ſpot of Ink, which ſpot hereafter is called the Center of the Glaſs.

SECT. II.

Of the Obſervation to be made by the Sun, and fitting all things for further progreſs.

TO perform this work of Obſervation, you are to do all things, as if you were to make a direct Sun-Dial, to the Center of the Glaſs, as the Gnomon; and that all common impediments may be removed, let all the panes of Glaſs, where the Reflecting Glaſs lieth, be taken down out of the way, that you may have convenient room to do that which now followeth:

1. Firſt, ſet an Horizontal Thread *in æquilibrio* with the Glaſſes Center.
2. Hang up a perpendicular Thread, betwixt the Sun and the Center of the Glaſs, ſo as that the ſhadow of it may paſs through the Center of the Glaſs; and in that poſition you muſt diligently obſerve where the ſhadow of the ſame perpendicular Thread, doth (at the ſame time) cut the Horizontal Thread. And to perform this the better, let your perpendicular Thread be bigger than ordinary; and beſides hold in your hand ſome fair Paper (which may better receive and repreſent to you the ſhadow of the Perpendicular Thread) ſo as that you may thereon ſee where the ſhadow of the Perpendicular Thread doth cut the ſhadow of the Horizontal Thread, and in the apparent interſection draw a ſlipping Knot (ty'd before for that purpoſe upon the Horizontal Thread) along the Horizontal Thread, till the ſhadow of this Knot fall into the former interſection of ſhadows; and when this work is done, (which will be troubleſom enough and ſo you will need one to help you) immediately take the Sun's Altitude.
3. And by that Altitude compute the Azimuth of the Sun, which is repreſented by the fore-mentioned ſlipping Knot, fixed in its due place as before.
4. By that Azimuth, and a Paſt-board (Horizontally apply'd to the Center of the Glaſs, and ſo lying level with the Horizontal Thread) inſert the Meridian Point, and the Points of all the other Hours, as is uſed in Direct Dials, in the Horizontal Thread, and there affix Knots ſeverally.
5. By a perpendicular Thread held up within the Room, and ordered

in the hanging ſo, as that you may ſee through it (at once) both the Meridian Knot, and the Center of the Glaſs; project the ſame Thread upon the top of the Room, this Projection ſhall be the Meridian Line, which paſſeth directly over the Center of the Glaſs.

6. From the Center of the Glaſs into this Meridian Line, direct your Semi-Circle, and elevate it to your Latitude, and ſo (by it) inject the North Pole into the ſame Meridian, which, in thoſe Windows that look towards the South, will fall within the Houſe upon the Cieling.

7. From the Center of the Glaſs to this North Pole extend a Thread for the Axis of the World, and for that purpoſe fit a Wire with a head like a Pin, then faſten that Wire into, or near to the Wood whereon the Reflecting Glaſs is laid, and bow down the Head of it, until it touches the Glaſſes Center; then faſten your Thread Axis to this Head of the Wire, at one end, and to the Cieling at the other end.

Thus are all things fitted for further progreſs in the Work. That which is hitherto delivered, no what differing from what is preſcribed for making Dials for the direct Rays of the Sun.

SECT. III.

Of further fitting the Work that is pre-required to the Reflecting of Hours.

Before any Reflection can be made, it will be requiſite, that the direct Hours be ſo expreſſed, that they may from thence be brought into the Glaſs, and from thence again Reflected to the Cieling or Sides, or any other part of the Room. And the readieſt way that I can find for this purpoſe is this.

HAving before prepared your direct Axis, and likewiſe the Hour Points upon the Horizontal Thread, you may by them project (with your Eye) each Hour ſeverally without the Window, by one of theſe two ways:

1. Lay a long Stick or Pole without the Window (upon two Reſts) about half a yard from the Reflecting Glaſs, outwards towards the Sun, and let it lie (as low or) near about the Level of the Reflecting Glaſs: There is no exactneſs required in this.

1. Nail down ſomewhat near, and as low at leaſt as the Reflecting Glaſs, ſome little Stick or Wand upon the Stool (or to ſome other part) of the Window, ſo as that it may be turned about the Nail as a Center Pin; let it lie about half a yard without the Window towards the Sun, and ſome ſmall quantity within, that it may be conveniently turned about with ſome ſtiffneſs; make a notch in the very end of the Stick, that a Thread may lie and ſtay in it without ſlipping.

2. When things are thus fitted you are firſt to project each of the direct Hours ſeverally (by help of the direct Axis, and of the Hour Points upon

upon the Horizontal Thread) upon the Posts of the Window. The way is, by reposing the Knot (of that Hour you would project) upon the Thread-Axis, and then your Eye (limited to that posture) will project the Axis, (or the fore-said Hour) upon the Window Posts. Of which appearance or Projection of the Axis, take notice of that Point only upon the Window sides, which is nearest to the extremity thereof, or which looketh most

Upon the Pole laid without the Window, in that point of the Post fasten a Nail.

3. Upon that Nail, at the very entry of it into the Post, hang a Thread, and put the same Thread upon the out-side of the Stick, or Pole that is laid without the Window, and so turn it under again, and bring it into the Window, where you may hang some small weight at the end of it only to keep it strait.

4. Set your Eye again in the self-same Position, or Posture that it had before, that is, let the Axis be reposed again upon the Point wherein the Nail was driven, and on which the Thread now hangeth, and keeping your Eye fixed there, remove the Thread which goes about the Stick, until you see it justly close with the Axis, and when you have situated the Thread in this Position, let it stand; for now the Center of the

Upon the extremity or notch of the Stick lying without the Window, there in that Point of the Post fasten a Nail.

3. Upon the Nail (where it enters upon the Post) hang a Thread and put the same Thread into the Notch at the end of the turning Stick, and hang some little weight at the end of it only to keep it strait. Thus is there a Thread extended from the Nail to the end of the Stick.

4. Set your Eye again to the same posture that it was before, that is to say, repose the Axis again upon the Point whereon the Nail was driven, and whereupon the Thread now hangeth, and keeping your Eye fixed there, turn the moveable Stick, in the Notch whereof the lower end of the Thread rideth; turn it, I say, until the whole Thread fall justly in with the Axis; and when you have situated the Thread thus, let it stand; for now the Center of the

Glass, and this newly situated Thread do lie in the Superficies of that Hour which you are about to project; and consequently wherever the Sun is in the plane of that Hour, then will the shadow of the Thread fall upon the the Center of the Glass, which is the Ground of the whole Work of Reflection, which now followeth: Let this be called, *The Directing Thread.*

SECT. IV.

Of Reflecting the Hour-Lines from the Hour Thread to the Cieling.

1. TO prepare yet further for the Reflection of the Direct Thread, fasten a Nail upon some Post of the Window or other (if it be near right over the Glass, it is the more convenient for use) and on it tie a Thread, which for distinction sake, call, *The Reflecting Thread*, and

let

let the length of it be ſuch as may reach to the Stool of the Window, or any other Stool ſet for the purpoſe in the way, upon the edge whereof this Reflecting Thread may be ſtayed from wavering; and for more ſtability, hang a Weight at the end of it.

2. Upon the ſame head of the Wire, tie another Thread, and let it hang looſe by you, until need ſhall call for it; call this, *The Projecting Thread.*

3. Look now into the Reflecting Glaſs, until you ſee the Projecting Thread, which if you have once or twice tryed, you will eaſily find without long looking. And when you do ſee it, carry your Eye, according to the length or courſe of the Thread, ſtill keeping it in your Eye, until you have brought your Eye as much over the Reflecting Glaſs, as conveniently you can; and then alſo ſee that your Eye lay the Hour Thread juſt in the Center of the Glaſs. When this is done, move the Reflecting Thread till you can percieve it to lie juſtly between your Eye and the Glaſſes's Center; and likewiſe the direct Thread appearing in the Glaſs; that is, let all be done ſo juſtly, that your Eye may at once ſee all theſe three juſtly together in one Point, namely, the directing Thread (repreſented in the Glaſs) the Reflecting thread, and the Center of the Glaſs; and when you ſee them all three together, hold your Eye as far off as you can, that they may appear in more exactneſs; then let the Reflecting Thread reſt againſt the edge of ſome Stool, ſet for that purpoſe and bring the ſlipping Knot, that it alſo may juſtly (to your ſight) lie upon the Glaſſe's Center, and the repreſented Directing Thread: and ſo let them reſt.

4. Then take the Projecting Thread, and draw it out to the Cieling, ſo as it may touch the ſlipping Knot before-mentioned; and when it doth ſo, note in what Point it toucheth the Cieling or Walls, *&c.* of the Room. Note that Point (I ſay) for one Point (of the former Directing Thread) Reflected.

5. As in the laſt 3 Section, ſo in this place again, look for the ſame Directing Thread in the Glaſs, and follow it down till your Eye come as low (I do not mean near)) to the Glaſs as you can; and keep the repreſented Thread upon the Center of the Glaſs: Then bring the Reflecting Thread betwixt your Eye and the Glaſs; and move it and the ſlipping Knot upon it until your Eye (at a good diſtance off) can ſee this Knot, the Center of the Glaſs, and the repreſented Thread, all three juſtly together, one upon the other. And then fix your Reflecting Thread.

6. Afterwards take the Projecting Thread, and by it (as in the laſt 4th Section) project the Point or ſlipping Knot up or down to the Cieling or Walls, or Floor of the Room; ſo ſhall you get a ſecond Point (of the ſame Directing Thread) Reflected.

7. Then having two Points of one Hour found out, you may extend your projecting Thread to one of them, and with your Eye repoſe the Thread upon the other of them; ſo ſhall the appearance of the Thread give you all the Points, through which the Reflected Hour Line muſt be drawn. And by this manner of Work, the ſame Reflected Hour may be continued, or carried quite through the Room.

8. In the ſame manner all the other Hours muſt be drawn ſeverally. Firſt, They muſt be ſet or projected directly into the Thread Hours, called, *The Directing Threads* (as in the 4th *Sect.* of the IIId.) and afterwards from

Mmmm thence

thence they are to be Reflected, as in this 4th and the Sections hereof is ſhewed.

CHAP. VIII.

How the former Precepts are to be apply'd to Windows looking Northward.

1. ALL the Obſervation, and laying of the Horizontal Thread within the Room, *&c.* is to be done as before.

2. But in theſe Windows, the Direct Axis will riſe from the Glaſs upwards without the Room (not within it, as the laſt did) There muſt therefore ſomething be ſet up to receive it, that it may be fixed from the Center of the Glaſs to that which is to receive it.

3. Then you are to lay ſome long Stick or ſmall Pole (at ſome convenient diſtance from the Glaſs) without the Window, laying it as low as the Glaſs: This is to receive the direct Hours, which to place right do thus.

4. Project with your Eye the Hour Points (or Knots that are upon the Horizontal Thread) upon the direct Axis, ſo ſhall the Shadow (or Projection) of the Axis, give the ſame Hour upon any Object that lies in the way, as namely, upon the Pole that way laid on purpoſe to receive it. And this Work you may do either of theſe two ways:

First Way,

Make Marks only upon the Pole, for each ſeveral Hour, and when they are all Marked, tie a Thread to the top of the true Direct Axis, or, take the true Direct Axis it ſelf (or Pole of it) and then ſtretch that Thread to any of the formerly noted Points; the ſame Thread ſhall repreſent each Direct Hour, according as it is applyed to each ſuch Point. Theſe are the Direct Hours, and may be Reflected as is taught before.

Second Way.

The work is the ſame as before to make Marks upon the Pole for the ſeveral Hours, which being done, you muſt firſt Reflect the Pole, and mark a point of it within the Room; this Point is the Reflected Pole: Then reflect each Point upon the Pole into the Room, ſo have you the Hour-Points Reflected. After this faſten a Thread to the Reflected Pole, and then ſtretch the ſame to any of the Reflected Hour Points; and then project this Thread upon the Glaſſes Center ſo ſhall the Thread ſhew where to draw the Hours. Thus do for all the Hours.

But if ſome of theſe Points upon the Pole fall to be below the Glaſs (and ſo cannot be Reflected) then ſtretch a Direct Thread from the true Pole to any ſuch Hour; and do further, as in the firſt of theſe ways; ſo theſe North Windows are compleated too.

Note,

Note, Inſtead of the 3d. Section of this Direction where you are preſcribed to lay ſome ſmall Pole, you may nail down a ſmall Stick, or Wand, upon the Stool of the Window, as is before preſcribed Sect. 3. Num. 1. of South Windows.

CHAP. IX.

How to make East and West Dials to aſlope Glaſs upon any Walls or Cieling.

THeſe Windows that look near to full Eaſt or Weſt, cannot have any Direct Axis extended as other (North and South) Windows have, becauſe the Poſts of the Window will ſtand in the way, ſo is this here added, that the Horologiographer ſhould not be left deſtitute. And now, although no Axis (either Direct or Reflected) can be extended, yet the Direct North Pole may be found (and then the Dial made) in this manner:

1. Having ſet the Horizontal Thread within the Room, even with the Center of the Glaſs, make an Obſervation of the Azimuth, as is before directed in South Windows.

2. Then amongſt many ways take this, Stretch a Thread from the Center of the Glaſs to the Knot of the Azimuth, ty'd in the Horizontal Thread; this Thread ſo ſtretched ſhall repreſent the obſerved Azimuth. Or if you cannot (becauſe of ſome hinderances that ſhall lie in the way) ſtretch out a Thread in that manner, lay on juſt over thoſe two Points (of the Glaſs and Horizontal Thread) and let it alſo be equidiſtant from them both, which you may do by your Compaſſes.

3. Aſſume ſome one Point of this Azimuth Thread for a Center, fixing ſome firm Point there, and call that Point the Center. Then upon Paſtboard (or ſuch like) protract the Azimuth and (the North or South part of) the Meridian, or the Angle that is made between them. Afterwards lay the Center of this Angle upon the fixed Center before mentioned, and direct one of the Legs of the Angle under the forenamed Azimuth Thread, ſo ſhall the other Leg of the Angle (if you hold it right, which your judgment will eaſily direct you in) deſign where the Meridian ſhall be, which project upon ſome Object (as Cieling or Walls) as the manner is, upwards to the North Pole.

4. In this Meridian, with your Semi-Circle, find the Pole, and (from the fixed Center to it) extend an Axis: This Axis is parallel to that which ſhould go up from the Glaſs.

5. Above and below this Axis ſtretch another Thread Parallel to it, at a good diſtance, which to do, there are many ways [as ſee the *Lemma* after theſe Precepts] which now I ſuppoſe known; ſo that now you have two Axes, by which you ſhall find the true North Pole to the Center of the Glaſs (though you cannot extend an Axis from thence) namely thus:

6. Repoſe (with your Eye) one of theſe Axes upon the Center of the Glaſs, and mark where it ſhadoweth upon ſome fit place to receive the

the Pole (a good way from the Glaſs, and if there be nothing to receive it, ſet up ſomething) there draw a Line. Then repoſe the other Axis upon the Center of the Glaſs, and mark where it ſeemeth to croſs the former drawn Line, that croſſing is the North Pole to the Glaſſe's Center.

7. Then having found the Pole, faſten a Thread at it; and without the Window lay a Pole as before ſhewed, as low, or lower than the Glaſs. The work that now remains, is to ſet Hours without the Window, that ſo they may from thence be Reflected into the Room.

8. Take the Pole Thread, and lay it to one of the Hour Points upon the Horizontal, and repoſe it with your Eye upon the Glaſſe's Center, that ſo through this projecting Thread you may at once ſee the Knot upon the Horizontal Thread, and the Center of the Glaſs. In this Propoſition the ſhadow of the Thread will Project two Points, one upon the Barrs or Poſts of the Window, and the other upon the Pole that lies without. You may ſo ſtretch a Thread from theſe Marks, and that Thread ſhall be the direct Hours without the Window; and you may try whether you have ſet it true by the Pole Thread applied again to the Hour Point in the Horizontal Thread. When the direct Thread is thus placed, you may Reflect it, as hath been before ſhewed.

LEMMA.

How by having one Thread extended in the Air, to ſet another Parallel to it.

FIrſt project the Radiation of the ſtanding Axis, that way that you mean to ſet up your new Axis; then in that Radiation let two Threads be extended, touching the Axis both of them, and both making Angles with the Axis (the nearer Right Angles the better) and both hidden in the former Radiation, and both faſtned; ſo theſe two Threads do keep both in one Plain, and both in the ſame Plain with the Axis; and the new required Axis is to touch theſe two Threads ſo placed: Wherefore extend another new Thread for a new Axis, which may touch theſe two Threads always; and in that touching Poſition try with your Compaſſes, until you find it equidiſtant from the other Axis. You may help your ſelf by ſetting any ſolid thing that may touch the firſt Axis towards each end, in a Point whereon the foot of the Compaſſes may ſtand without quavering, and ſo eaſily try whether and when the new Axis is Parallel to it.

Another way to ſet an Axis juſt under or over the firſt.

HAng up the two Perpendicular Threads towards both ends, that may touch the firſt Axis, and put ſlipping Knots upon them, in thoſe Points wherein they do touch; then put two more ſlipping Knots at one, or any equal diſtance below or above thoſe two firſt Knots: And when this is done, let the two Perpendicular Threads hang at liberty, and quietly. If now you extend a new Thread, that may touch theſe two laſt Knots upon the Perpendicular Threads, the ſame extended Thread ſhall be another Axis Parallel to the former. And this (as I ſaid before) muſt needs lie juſtly above or juſtly below the former Axis, and will do the buſineſs.

CHAP.

CHAP. X.

If a Flat Reflecting Glaſs ſhould by miſhap, be put out of his place, how to reſtore it again.

THough I ſpeak only of Flat Glaſſes, yet I intend to direct how ſuch a Flat Glaſs may be reſtored to its true Poſition, whether it be to lie Flatly or Obliquely. One may be thus:

Becauſe ſuch Glaſſes lie moſt commonly in Windows, or ſuch places, you may ſo, (when your Hours are drawn upon the Cieling or otherwhere) ſtretch a Thread from the Glaſs to any one Hour, and then with your Eye project the ſame Hour Line, or one Point of it, (if it be not ſo done before) upon ſome other Object then is the Cieling, ſuch namely, as ſtand either Perpendicular, or at ſome ſenſible Angle to the Cieling or Superficies upon which your Hours are drawn (as the Glaſs or Poſts of the Window) and make ſome mark of this Projection, with ſome Sign, or Note upon it, or Figure, that you may afterwards know again, to what Hour it belongeth; ſo do with ſome other Hours alſo, that is, two or three, or four Hours diſtant from the former; ſo ſhall you (by the foreſaid Hours, and their Marks, now mentioned) be able to reſtore the Glaſs, if it were taken away. In this manner:

By the two Hours, and their two Marks, you may find the reflected Axis again, by which the Hours were, or might have been projected at the firſt; for two Threads, being firſt faſtned to the two Hours, and theſe Marks, you may from thoſe Hours (and by their two Threads, cloſely touching them) ſtretch out two other Threads, and where they (upon thoſe conditions of touching the two new extended faſtned Threads, ſhall interſect one another, there is one Point of the Reflected Axis, and there is ſome ſet Mark or Point of Wood to be for a time fixed. So again, the ſame two Threads in the ſame manner extended, to touch two other parts of the firſt faſtned Threads ſhall find another Point of the Reflected Axis, at which Point again, another Mark or Point of Wood is to be faſtned. This projecting, or re-finding the reflected Axis, may be done other ways (as by the Eye) which they that have practiſed theſe Precepts in this *Book*, will be ready of themſelves to find without any more Directions.

Now in any part of this reflected Axis (with a Thread extended from the two fore fixed Marks, or Points of Wood quite along, as far as is needful will ſhew) you may fix the Glaſs again: I ſay in any part of it, if your Dial have nothing but hours in it, but if it be furniſhed with other Circles of the Sphere, then not any Point of the Axis, but one only Point where it ſtood before, muſt be found again, for that only will ſerve all turns: And the readieſt Directions to find that Point will be this:

If your Dials be furniſhed with Parallels of the Length of the day, count that Parallel which is equal to the day's length, in which you would reſtore the Glaſs, for along that Parallel ſhould the ſpot of Light move all that day: Wherefore you have no more to do but to prepare a Glaſs, and move it to

and fro upon a ſmall bit of Wax, till the ſpot of Light be Reflected upon the ſaid Parallel of the length of the day, and there fix it. The like may be done if the Parallel of the Signs (and not the length of the day) were inſcribed upon your Cieling; if firſt by the Planiſphere you find in what Parallel the Sun is upon that day in which you intend to reſtore your Glaſs. But if neither the Parallels of the length of the day, nor the Parallel of the Sun's courſe; but the Azimuths (or only the common Hours) be upon the Cieling, yet you may help your ſelf thus. At ſome convenient time of the day find by the Planiſphere what Altitude the Sun ſhall have upon that Azimuth or Hour, on the day you intend to reſtore the Glaſs, then (before that time of the day come) extend a Thread from the place where the Glaſs is to reſt, to ſome part of that Hour or Azimuth, for which you have before computed the Sun's Altitude, moving of it backward or forward along the ſaid Azimuth or Hour, till the Thread and Plummet of the Semi-Circle being apply'd thereto, hangs upon the Altitude before found; and where your extended String reſteth upon the Azimuth or Hour, make a Mark; and obſerve diligently when the Sun comes to that Azimuth or Hour: Then move the Glaſs in its place to and fro, till the ſpot of Light be Reflected upon the Point before found, upon the Azimuth or Hour; and there fix the Glaſs.

The End of the Eleventh TRACTATE.

REFLEX DIALLING,

SHEWING,

The Way to Draw all manner of *DIALS*, which ſhall ſhew the Hour by a Spot of Light, *Reflected* from a *Glaſs* upon any *Cieling*, or other *Object* whatſoever, without any reſpect had to the *Axis* of the *World*, either PROJECTED or REFLECTED.

AS ALSO,

Whether the Glaſs lie *Parallel* to the *Horizon* or *Oblique* unto it.

TOGETHER

Will all neceſſary *FURNITURE* belonging thereunto.

All performed by an eaſie INSTRUMENT fitted with Lines to that purpoſe.

By JOHN TWYSDEN, M.D.C.L.

The Twelfth TRACTATE.

CHAP. I.

The Deſcription of the Inſtrument.

LET there be a ſtrait Ruler of Wood or Braſs made, as AG, the length, breadth, and thickneſs, at Diſcretion: About the middle of it, or nearer to the end A, let the hollow B be made large enough to compaſs a Socket of Braſs, into which the Glaſs muſt be fitted, and ſo that the fiducial edge A B C, may be imagined to paſs thro' the Center of the Glaſs, when it is fixed. On the other ſide, as at F, may be made another hollow, like htat at B, to the end you may uſe either edge of the Ruler, as occaſion may ſerve; to the end of this Ruler muſt be added another at right Angles CM, made moveable, yet ſo ſupported by a Bracket E, behind, that it may ſtand ſteady at right Angles, and unto this let there be fitted a ſlipping Socket with a fiducial edge *h i*; let the piece CM be divided as a Tangent Line to the Radius B C, and of that length that it may contain about 47, or 48 degrees, which you need not divide beyond 45. On the other ſide KM, to a ſhorter Radius, let the Tangent Line be continued

tinued to 64 degrees, or thereabouts, which will be far enough for most Dials of this kind; the whole representing two sides of a Rectangular Parallelogram, or Carpenters Square, the one Leg longer than the other, all which by the Figure annexed, is easily understood.

CHAP. II.

Precepts for the Ready Use of this Instrument.

First, in the place where you intend the Glass shall lie, make fast some piece of Wood or Brass, exactly Horizontal, unto which, you may joyn some other large piece of Board, Past-board, or other, it matters not; so as it be made to stand firm and Horizontal, till the Dial shall be finished, and then taken away.

Secondly, Having upon any part of your fixed piece of Wood made a Mark, over which precisely shall be the Center of your Glass; upon this Mark as a Center describe so much of a Circle as is necessary, to as large a Radius as the Past-board will give way, and then the Sun shining, hold up a Thread, so that the shadow of it may pass through the Center of your Circle; and mark where it cuts the Cricumference, and at the same instant take his Altitude, and find his Azimuth, either trigonometrically, or by some Astrolabe: of all projections of the Sphere, I know none so exact for the performance of all things necessary for the making these Dialls, and the solution of all other Astronomical Problems, as that commonly called *Blagrave's Jewel*, now put out, every way much amended and altered by Mr. *John Palmer*, Rector of *Ecton* in *Northamptonshire*, my especial Friend.

Thirdly, having found his Azimuth, set off now the South or East Line, by help of a Scale of Chords made to the Radius of your formerly described Circle, we will take the Example of an East Dial: As for Example, In the Latitude of 52 deg. 15 min. I observed in the Tropick of *Cancer* the Sun's Altitude 15 deg. 00 min. By my Astrolabe I find his Azimuth, then from the East, or six of Clock Line was 19 deg. or 71 deg. from the Meridian or Midnight Line Northward, but because in this Example the Meridian could not be expressed, I set off 19 degrees upon my Circle to the right Coast, and there through the Center draw a Line, which shall represent the East Azimuth.

Fourthly, Your East or Meridian Line, if it may be, being thus drawn, have recourse to your Astrolabe, or by Trigonometry find these ensuing things. First, for all necessary Hours which will come upon the Dial, find the Sun's Azimuth, and likewise what Altitude it hath in that Hour and Azimuth; do this for the Tropick, the Horizon (in Dials made to Oblique Glasses) the Equinoctial, or for as many of the Sun's Parallels as you please; I have made choice of the Distance upon the Horizon, and Tropick of *Cancer*, for a Flat Rooff two are enough, because the Hours will be strait Lines otherwise if the Roof be concave, convex or any way un even, it will require the finding of more points; write these down, as in the Table ensuing.

In

In the Latitude of 52 *degrees,* 15 *minutes.*

Distances from the East on the Horizon.

Hours	deg.	min.	
4	36	00	*From East Northward*
5	18	40	
6	00	00	
7	18	40	
8	36	20	*From the East Southward.*
9	51	40	
10	65	30	
11	78	20	
12	90	00	

In the Tropick of Cancer.

Hou. H.	m.	*Azim. from East.* D.	m.	*Suns Altit.* D.	m.
4	00	37	30	02	00
5	00	25	40	10	00
6	00	15	00	18	30
7	00	03	30	27	30
8	00	09	00	37	00
9	00	22	30	45	30
10	00	40	00	53	30
11	00	62	30	59	20

The Sun's Azimuth, Altitude, *and* Amplitude, *for every* Hour *in the* Equinoctial *and* Tropicks, *calculated from* 50 *to* 65 *deg. of Latitude.*

HOURS.

		Before Noon. / *After Noon.*	XI		XI / I		X / II		IX / III		VIII / IV		VII / V		VI		V / VII		IV / VII	
Latitude 50 deg.	Trop. ♋	Azi.	90	00	60	38	37	26	20	12	6	49	4n	53	15	36	26	19	37	24
		Alt.	63	30	61	02	54	41	46	15	36	53	27	15	17	47	8	48	00	37
	Equinoct.	Azi.	90	00	70	44	53	00	37	28	23	52	11	36	00	00				
		Alt.	40	00	38	23	33	50	27	02	18	45	9	35	00	00				
	Trop. ♑	Azi.	90	00	75	45	62	04	49	16										
		Alt.	16	30	15	18	11	30	6	24	☉ *set*									
	Amplitude		90	00	78	24	66	09	52	33	37	00	19	17	00	00	19	17	37	00
Latitude 51 deg.	Tropi. ♋	Azi.	90	00	61	31	38	37	21	20	7	31	4n	20	15	18	26	10	37	24
		Alt.	62	30	60	09	54	04	45	53	36	45	27	20	18	03	9	14	1	13
	Equinoct.	Azi.	90	00	70	57	53	25	37	50	24	09	11	45	00	00				
		Alt.	39	00	37	26	33	02	26	25	18	20	9	22	00	00				
	Trop. ♑	Azi.	90	00	75	49	62	10	49	40										
		Alt.	15	30	14	20	10	57	5	38	☉ *set*									
	Amplitude		90	00	78	14	65	50	52	09	36	38	19	02	00	00	19	02	36	38
Latitude 52 deg.	Tropi. ♋	Azi.	90	00	62	20	39	41	22	16	8	19	3n	43	14	59	26	01	37	23
		Alt.	61	30	59	16	53	26	45	31	36	37	27	25	18	19	9	41	1	50
	Equinoct.	Azi.	90	00	71	13	53	46	38	14	24	28	11	55	00	00				
		Alt.	38	00	36	29	32	13	25	48	17	56	9	10	00	00				
	Trop. ♑	Azi.	90	00	75	53	62	15	49	24										
		Alt.	14	30	13	12	10	04	4	53										
	Amplitude.		90	00	78	05	65	32	51	46	36	14	18	47	00	00	18	47	36	14

			HOURS.								
		Before Noon.	XI	XI	X	IX	VIII	VII	VI	V	IV
		After Noon.			II	III	IV	V		VII	VII
Latitude 53 deg.	Trop. ♋	Azi.	90 00	63 05	40 42	23 12	09 03	3n 18	14 40	25 52	37 21
		Alt.	60 30	58 23	52 47	45 08	36 28	27 28	18 34	10 07	02 26
	Equinoct.	Azi.	90 00	71 27	54 08	38 3[illegible]	24 45	12 05	00 00		
		Alt.	37 00	33 33	31 25	25 11	17 31	08 58	00 00		
	Trop. ♑	Azi.	90 00	75 56	65 19	49 27					
		Alt.	13 30	12 24	09 11	04 07					
	Amplitude		90 00	77 55	65 15	51 23	35 52	18 33	00 00	18 33	35 52
Latitude 54 deg.	Tropi. ♋	Azi.	90 00	63 48	41 40	24 06	09 47	2n 49	14 20	25 42	37 19
		Alt.	59 30	57 29	52 08	44 44	36 14	27 31	18 49	10 33	03 03
	Equinoct.	Azi.	90 00	71 40	54 29	38 58	25 02	12 14	00 00		
		Alt.	36 00	34 36	30 36	24 34	17 0[illegible]	08 45	00 00		
	Trop. ♑	Azi.	90 00	75 59	52 23	49 30					
		Alt.	12 30	11 2[illegible]	08 18	03 2[illegible]					
	Amplitude		90 00	77 46	64 58	51 02	35 31	18 19	00 00	18 19	35 31
Latitude 55 deg.	Tropi. ♋	Azi.	90 00	64 28	42 36	25 00	10 29	2n 13	14 00	25 32	37 16
		Alt.	58 30	56 35	51 28	44 19	36 08	27 34	19 04	10 59	03 39
	Equinoct.	Azi.	90 00	71 53	54 50	39 19	25 19	12 23	00 00		
		Alt.	35 00	33 39	29 47	23 56	16 40	08 32	00 00		
	Trop. ♑	Azi.	90 00	76 02	62 28	49 31					
		Alt.	11 30	10 27	07 24	02 35					
	Amplitude.		90 00	77 37	64 41	50 41	35 11	18 07	00 00	18 07	35 11
Latitude 56 deg.	Tropi. ♋	Azi.	90 00	55 00	43 31	25 53	11 0[illegible]	1n 31	13 40	25 2[illegible]	37 13
		Alt.	57 30	55 41	50 46½	43 53	35 57	27 36	19 18	11 25	04 15
	Equinoct.	Azi.	90 00	72 05	55 09	39 40	25 35	12 32	00 00		
		Alt.	34 00	32 42	28 58	23 17	16 14	08 19	00 00		
	Tropi. ♑	Azi.	90 00	76 05	62 31	49 33					
		Alt.	10 30	09 29	06 31	01 50					
	Amplitude		90 00	77 29	64 25	59 20	34 5[illegible]	18 55	00 00	18 55	34 51

CHAP.

CHAP. IV.

How to fasten the Glaſs *and draw the* Hours.

HAving gone thus far, your next work will be to faſten your Glaſs in its Socket, to what Obliquity you pleaſe, at adventure, and ſo to order all things that the Center of of your Glaſs may be directly over the Center of your formerly deſcribed Circle, and the height of the Center of your Glaſs, equal to the thickneſs of your inſtrument; ſo that the hollow part of the Ruler encompaſſing the Socket, the fiducial edge may paſs through the Center of your Glaſs, which you may mark with a little ſpeck of Ink, till your Dial is done.

The Hours are to be Drawn in this manner: Firſt, get the Points where the Hour Lines ſhall cut or touch the Horizon in the Cieling, by which Points the Horizon it ſelf may at the laſt be drawn. Theſe Points you ſhall get, as in this Example in the Latitude of 51 deg. 00 min. when the Sun riſeth at Four, I find by the Table annexed in the Column belonging to that Latitude, that his Amplitude or Diſtance from the Eaſt Northward, is 37 deg. 19 min. Place therefore the Radius of your Inſtrument to that Amplitude or Azimuth, marked before in your Circle upon the Horizontal Board; and the Socket being ſet to the Sun's Altitude, which is 60 deg. 00 min. obſerve, with your Eye, where the fiducial edge of the Socket, in the point of interſection with the Altitude, will be reflected from the middle of the Glaſs, which you ſhall find always in the ſame *Azimuth*, if the Glaſs be Horizontal; but if the Glaſs be Oblique to the Horizon, the Reflection will ſwerve toward the Pole Zenith of the Glaſs, more or leſs, as the Obliquity is. Hang a Thread, or faſten it in any place, ſo that holding it between your Eye and the Glaſs, it may catch this reflected Socket where-ever it comes, and where it cuts the Thread tie a ſlipping Knot. Now a Thread extended from the Center of this Glaſs, by this Knot to the Cieling, ſhall touch the Point where the Hour Line of Four is to cut the Horizon. In like manner you ſhall find the Points for 5, 6, 7, 8, if need be; and if you will alſo, for 9, 10, 11, and 12, working by the Amplitudes of the ſeveral Hour Lines, as you did by the Amplitude of Four. A Line drawn through theſe Points, ſhall repreſent the Reflected Horizon, if you ſhall have a deſire to draw it.

Then laſtly, Go to your Table for the Tropick of *Cancer*, and in the Azimuths marked in your Circle, and belonging to every Hour you intend to draw, place the Radius of your Inſtrument, as before you did for the interſections of the hours with the Horizon, and move the Socket in the upright Ruler of your Inſtrument to the degree of Altitude belonging to that hour you intend to draw, which you ſhall find in your Table calculated for the Elevation of the Pole, from 50 deg. to 56. deg. and with your Eye Reflect it by help of a Thread hung up any where, and held between your Eye and the Glaſs in the ſame manner as you did the Reflected Horizon; and where a Thread extended from the Center of the Glaſs by the Knot touches the Cieling, that is the Point for that Hour, and

a

a Line drawn from thence to its correſpondent in the Horizon, ſhall repreſent the Line where the Reflected ſpot of Light will be for all the year.

As for Example in the Latitude of 51 deg. 00 min. I find by my Table that the Sun's Amplitude or Azimuth from the Eaſt Northward in the Tropick of ♋ is 37 deg. 19 min. at the hour of Four. There I place the Radius of my Inſtrument, and move the Socket to 1 deg. 13 min. the Sun's Altitude in that hour, then the Inſtrument remaining in this ſituation, I reflect the Socket as before was ſhewed. This you muſt repeat for ſuch Hours as you intend to draw, and finiſh your Dial if you think fit.

Note, When you cannot readily find the Image of your Socket, in the Glaſs, being narrow, you ſhall lay a broader piece upon the narrower, and having found it in the broader (which will ſoon be done) keep your Eye upon it till ſome body remove the broader Glaſs, and you ſhall eaſily find it in the narrower, for there about it will paſs.

Note, alſo, That if you find not your Latitude in the Tables, you muſt work a proportional part, in this manner: Suppoſe I deſire to draw a Dial in the Latitude of 51 deg. 32 min. and would find where the Hour of Four interſects the Horizon; I find not that Latitude, but find 50 deg. 00 min. and 51 deg. 00 min. In 50 deg. 00 min. I find the Amplitude at 4 hours 00 min. is 37 deg. 24 min. In 51 deg. 00 min. it is 37 deg. 19 min. their difference is 5 min. Therefore, As 1 deg.: to 5 min. : : So 32 min.: to 2 min. 40 ſec. which being ſubducted out of the Amplitude belonging to the Latitude of 50 d. 37, 24 ſhall give you 37 d. 21 min. 20 ſec. the Amplitude required. Or, adding it to the Amplitude of 51 d. 00 m. you ſhall find the ſame thing.

CHAP. IV.

Of the Furniture *of* Dials.

THE Parallels of Declination, of Altitude, the Azimuths, Proportions of the ſhadows of their Gnomons, and the like, commonly called the *Furniture of Dials*, may be eaſily inſerted by this inſtrument, if any man ſhall deſire it. Though to ſpeak my own judgment, I think theſe kind of additions rather for Ornament than uſe. Firſt, Becauſe they are many of them in their own nature difficult to deſcribe, being Sections of a Cone, and muſt therefore be drawn from many points, which hath ſome difficulty in the performance, except where they fall out to be Circles, which caſe will only happen where the Plain paſſeth by the vertex of the Cone makes Right Angles with the Axis, there the common Section is a Circle. If the Plain touch the Cone, it will be a Parabola. If it cut it, an Hyperbole. Laſtly, If it neither makes Right Angles with the Axis, and neither cuts, nor touches the Cone, it will be an Ellipſis or ſtreight Lines, as the Azimuths in a Flat Rooff.

Secondly,

Secondly, becauſe when they are Drawn, every Aſtrolabe will reſolve the Problems more truly than they will.

I might add a third Reaſon, becauſe the multitude of Lines often hinders thoſe that are not uſed to them, to tell the Hours of the day, which is the chief uſe of Sun Dials, eſpecially of thoſe of this kind, where the ſhadow of one Point of the Axis gives the Hour.

Yet, leaſt any ſhould think this Inſtrument imperfect, I ſhall ſhew the Deſcription of ſome of them, and leave the reſt to the Induſtry of every Man.

CHAP. V.

The Parallels *of* Declination.

THeſe are of as great uſe as any, becauſe the two Tropicks being the Parallels of the greateſt Northern or Southern Declination, may ſerve to limit or bound the Dial, and for them I need add no new Precept, having before in the third Chapter taught you the Deſcription of the Tropick of ♋. The Tropick of ♑ is deſcribed in the ſame manner by help of your Table, placing your Inſtrument to the Azimuth belonging to every Hour, and marked in your Horizontal Circle, and Reflecting the Socket, being before placed to the due Altitude. If you deſire the intermediate Parallels, either you muſt take the pains to Calculate Tables or by an Aſtrolabe, you may perform it exactly enough for this purpoſe.

CHAP. VI.

The Parallels *of* Altitude.

THe Parallels of Altitude are inſerted after this manner, not much differing from the former. Suppoſe I would inſert the 20th. Parallel of Altitude. Move the ſlipping Socket to 20 degrees in the Ruler, and the Radius being placed in any part of the Horizontal Board, Reflect with your Eye, by the help of a Thread, and a ſlipping Knot the image of the Socket, and carry it to the Cieling; do thus till you have found as many Points as you Pleaſe, through which a Line drawn, ſhall repreſent that Almicanter.

CHAP. VII.

The Proportions of the Shadows *to their* Gnomons.

THese are no other than Circles of Altitude to a determined proportion, and may thus be set on. Consider first, what proportion you desire to express. As for Example, I desire to know when the Shadow is double to the Radius. I take in my compasses the length of the lesser Radius of my Instrument, and upon the upright Ruler from 00 deg. 00 min. measure that length twice, you will find the Compasses to fall upon 63 deg. 30. min. to that degree and minute, set your moveable Socket, then your Instrument being placed as before is taught, *viz.* That the fiducial edge of it, pass through the Center of the Glass, remove it upon the Horizontal Board, from place to place, and reflect several Points through which draw a Line. At all times when the Spot is in that Line, the shadow of all upright things whatsoever, shall be double to their length; by which means you may find what height any Steeple or the like is, by measuring the shadow of it. In the same manner may all other Proportions be inserted.

CHAP. VIII.

To put in the Azimuths.

LOok what Azimuth you desire to express: As for example, I desire to put in the 10th Azimuth from the Meridian. First, upon your Horizontal Circle, mark that Azimuth, and next examine what Altitude the Sun hath in that Azimuth, in any parallel you think fit, or which is most proper to be made use of, and to that Altitude set the Socket, and place your Radius in the said Azimuth, then reflect the image of the Socket, and carry it to the Cieling, it will meet with the parallel if you have wrought truly, there make a mark. Do this for the Horizon, where the Sun hath no Altitude, and mark the Reflected point, though those two, draw a strait Line, if the Roof be flat, otherwise you must seek more points. After the like manner may the unequal hours, the degree of the Sun that culminates, and such like, be inserted, which I leave to the industry of every Practiser to perform. I shall now shew a ready way by this Instrument to make Dials to a flat Glass, these precepts hitherto being fitted to Glasses that lye aslope or Oblique, whether Convex, Flat, or Concave.

CHAP. IX.

How to draw the Hour-lines *to a* Glaſs *that lies* Parallel *to the* Horizon.

DO as you as you are directed in the foregoing precepts only inſtead of Reflecting with your Eye you may now place the Radius of your Inſtrument, ſo that the upright Ruler may be within the Room then applying it over in the Azimuth given for that Hour, move the Socket to the Altitude of the Sun in that Hour, and from the Center gently extend a Thread which ſhall ſhew you one Point, do this for as many Parallels as you deſire, if the Roof happen not to be Falt, otherwiſe two are enough.

For example, in the Latitude of 51 deg. 30 min. I draw a Meridian if I can, which is likewiſe an Azimuth, and find that in the Tropick of *Cancer*, the Sun will then be 62 deg. 00 min. high, to which I move the Socket, and gently extend a Thread by it to the Roof which ſhall give the point required. Do this for the Equinoctial, and through the Points found draw the Hour Lines.

ANO-

ANOTHER WAY OF REFLEX DIALLING, BEING. The Extract of a LETTER Written by Mr. IM. HALTON from *Grays-Inn.*

SIR,

"BUT that my occasions do and will detain me yet for some time "in Town, I should not have given you this trouble of a Letter; "for I purposed in my first Vacation from business to have seen "you; yet because in our last discourse, there was something "started of *Reflexed Dialling*, the Theorie whereof I told you, I thought "I could manifest in Two or Three *Diagrams*, and we not having oppor- "tunity *propter locum ambulandi datum*, to design the same, whereof you "seemed a little earnest, is the occasion of this, and the rather for that I "am not certain of seeing you.

First therefore, you are to take notice of this general Synopsis of Dials or Plains, whereon Dials may be described.

All Plain Superficies's whereon Dials may be described, are

- *Horizontal*
  - *Horozontal* 1
- *Perpendicular*
  - *Direct*
    - *Meridian* or *Polar*
      - *East* 2
      - *West* 3
    - *Prime Vertical*
      - *South* 4
      - *North* 5
  - *Declining*
    - *South*
      - *East* 6
      - *West* 7
    - *North*
      - *East* 8
      - *West* 9
- *Re* / *In* —*clining*
  - *Direct*
    - *Meridian*
      - *East* 10
      - *West* 11
    - *Prime Vertical*
      - *Equino.* 12
      - *Polar* 13
      - *Neutral* 14
  - *Declining*
    - *South*
      - *East*
        - *Polar* 15
        - *Non Po.* 16
      - *West*
        - *Polar* 17
        - *Non Po.* 18
    - *North*
      - *East*
        - *Polar* 19
        - *Non Po.* 20
      - *West*
        - *Polar* 21
        - *Non Po.* 22

So

So that the names of the Dial Plains are in number 22. The firſt admits of no variety; in others the ſame direction or calculation will ſerve for two of one kind, in ſome for four.

Now for the particular deſcription of each, ſo many have made it their buſineſs and ingenuity, that here ſhall be no more ſaid than what is already evulgated, which is more than ſufficient, although I could *Symbolum offerre*, and that as currant as ſome of the reſt; but becauſe the occaſion is *Reflexed-Dialling*, and that from a Plain and Reflecting Superficies howſoever poſite, know that this Superficies muſt neceſſarily be ſome one of the 22 varieties abovesaid, this is proved *inductivè*, by a perfect enumeration of all the ſingulars; for all Plains muſt ſingularly be in ſome one of theſe 22 Poſitions.

2. Again, the Plain of the Glaſs (conſidered as an ordinary plain for a Dial) muſt be taken as a plain in a Counter-poſition to that ordinary plain, as for inſtance in the Horizontal, an Horizontal Glaſs reflects an Horizontal Dial, as ſhould ordinarily be made to the Antipodes of the ſame place reflected; and ſo the like in the reſt of the plains, where you muſt be ſtill ſure to apprehend the plain of the Glaſs to make an Antipodical Dial to the ſame plain taken with a reflection.

3. As all Dials in their delineations or tracing of their hour-lines, reſpect their proper Axis, Horizons, and Equators, ſo likewiſe do theſe the ſame in their reflexed poſture; and here how you are to proceed to argue and ſtate theſe, ſo as you may take your practice in them, as in the ordinary plains, I ſhall be ſo free with you as to give you my conceptions and therefore,

4. Becauſe the Poles of the Equator and Horizon are ſo called in the common Nomenclature, as they are Perpendiculars, ſo for that reaſon ſhall I call the Perpendicular of the Glaſs, the Pole of the Glaſs, concerning which Pole, take theſe 4 Theorems.

That the Azimuth.	*upon which the Pole of the Glaſs is found compared with the*	1 *Meridian is the Declination.*	*of that Glaſs*
		2 *Horizon, is the Re-/In-clinat.*	
That the Hour-lines.		2 *Meridian, is the Inclination of Meridians, or difference of longitude.*	
		4 *Equator is the latitude or altitude of the Stile,* viz. *if it lie on the under or South ſide of the Equator South latitude, otherwiſe North latitude.*	

5 How to find this Pole of the Glaſs, the Glaſs it ſelf being ſo ſmall, and ſet within a Socket, as no Inſtrument can be applied to the Plain of it, there are two ways.

1. Geometrically; For ſuppoſe the Sun ſhining on the glaſs at C, the ſpot or reflection ⊙ at D. A Ruler, finger, or ſuch like thing, held up at B, ſo as the ſides of a Triangle B C D may be meaſured. Then the ſide D B cut in E by the 6 lib. *Euclid* prop. 3, ſhall give C E the Pole of the Glaſs. Then an Horizontal Paſtboard applyed to C (the Me- *Figure* I.

ridian being first found thereon) will by a Perpendicular Thread hung up, give you the Pole of the Glass, and a Quadrant Applyed to that Pole his Altitude or Depression in respect of the Horizon.

2. By Trigonometry, or Calculation; For the Sun shining upon your glass take his Altitude, and at the same time mark with a Pencil the spot or reflection; for by this (without the Sun shining any more) there is enough to draw the whole Dial with all the lines of the Globe; for supposing C in the Center of the Earth (as all Nodus's of Styles are supposed) and C O the spot or Reflection to pass into the Heavens into a certain part as C ⊙, which comes from thence. It is not to be doubted that the Arch of a great Circle O ⊙ would be made thereby, the ½ whereof would be C φ the pole of the Glass, for the Angles of incidence and reflection are equal, both in respect of the Perpendicular, as also the plain of the Glass, And so from the Azimuth and Altitude of the Sun taken, as also of the spot, the Azimuth, Altitude, Hour-lines, and Distance from the Equator of the Pole of the Glass (the four things which are before directed) are easily found.

6. For the speedy finding of the reflected Axis both of the Equator and Horizon (for without these the reflected hours and Azimuths are not to be drawn) as also the reflected Horizon, Equator and Tropicks, there are two ways.

1. By Instrument, 2 By Calculation. The first way directs the second, and so of the second I shall say but little, that my Letter may not swell; And for the first, for Example, I will propound the Horizontal Instrument of the place, where the Dials are intended to be drawn, suppose at *London*, where the Latitude is 51 deg. 32 min. So then let this be the Question, which is propounded in *Centesim*'s of degrees.

PROBLEM.

Figure II. *In the Latitude N. 51d. 53c. ⅓ the Sun being in the first scruple of* Cancer, *having post meridional Azimuth from the South* 50 *deg.* 85 *c. and Altitude* 53 *deg.* 75*c. casts from a Glass a reflection* O *of post meridional Azimuth from the North* 21 *deg.* 74 *c. and of Altitude* 26 *deg.* 69 *c. I desire to know the Plain.*

1. *SOLUTION.*

IN the Horizontal Diagram of the Latitude proposed, let the Sun ⊙, the spot O, the Zenith Z, the Pole of the Glass φ, and the Azimuths and Altitudes be laid down according to the Data's in the proposition, and the manner of the Diagram, *Quæritur* ⊙ O, the ½ whereof ⊙ φ, and so Z φ.

And again P φ and P Z φ equal to the declination of the Glass, *viz.* N A.

Also twice Z φ = Z E the reflected Zenith of the glass, and E X = 90 deg.

And V X Z the proper Horizon or plain of the Glass.

Lastly, Twice P φ gives you P D the reflected Axis, &c. for the reflected Zenith and the reflected Axis of the Glass, are those whereby the Hours and Azimuths are to be drawn; which together with the Equator and Horizon (because they only are great Circles and bisect the Globe) will be strait lines *in plano.*

But

But becauſe, as perhaps, through haſte (and the ſhort contraction of this, which I had rather have diſcourſed than thus made up into a Letter) any error may have happened in the deſigning of the Triangles upon the Horizontal Diagram, take this ſecond Solution by the Globe.

2. *SOLUTION.*

THE Pole of the Glaſs being as by the fifth found, by his Azimuth and Altitude aſſign a point upon the Globe, by ſome piece of white paper or other thing clapt thereon, from that point with your Quadrant of Altitude uſually made therewith, or rather Semi-circle of Steel, Braſs, or Whale-bone, application being made to the Pole of the World, Zenith, two points in the Equator and Horizon (becauſe great Circles) Tropicks, *&c.* the oppoſite equal Arches thereof, ſhall give you the reſpective reflexed points; having always a regard from this point or Pole of the glaſs aſſigned, that you make the Angles of Reflection equal to the Angles of Incidence. From hence now ſome neat Concluſions may be deduced, ſuch as theſe:

1. Firſt, That the Sun being at the point D (that is having North Declination 19 deg. 43 c. $\frac{1}{3}$, poſt-meridional Azimuth 80 deg. 31 c. $\frac{2}{3}$; Altitude 32 deg. 53 c. $\frac{1}{3}$, and Hours $4\frac{1}{8}$) ſhall give a reflection to P, that is parallel to the Axis of the World, and ſo by conſequence the Sun in his own poſition to the Glaſs (if by obſervation you watch that moment) ſhall ſhew you the reflected Axis of the Glaſs.

   And ſo at *London* this reflected Axis is found, when the Sun is in the Meridian having North Declination 13 deg. 6 c. $\frac{2}{3}$, the plain of the Glaſs lying Horizontal.
2. By this the Superficies of the Glaſs, or the Plain of the Glaſs, appears to be one of the 22 varieties of Plains, and that it declines 60 deg. and reclines 54 deg.
3. That by the plain of the Glaſs repreſented in the Horizontal Diagram by V X Y, you have the Hour-lines expreſſible upon that Plain, or which can be reflected by that Glaſs, and alſo the time of the Year when the Sun will firſt ſhine thereon, and the continuance.
4. That without any Glaſs, you may from a point taken, aſſign a reflexed Axis where you pleaſe, by an Azimuth and Altitude taken to your own fancy; as ſuppoſe at D, then will φ the Pole of your Glaſs be found as before, and you muſt be careful in bringing the Center of your Glaſs into this point, and ſo place it, which is alſo very feazible ſeveral ways.

7. For the practice, or making of theſe Dials, with all the Furniture thereof (the Theory being thus laid down) I ſuppoſe you are well enough acquainted therewith; I ſhould propound for my own practice any one of theſe.

1. Having got the reflected Axis, which will always paſs through the Center of the Glaſs both into the Air and into the Room [if the tranſome of your Window lie not directly in the Meridian] and having erected a Paſte-board, or ſuch like thing at Right-angles thereto, parallel to the reflected Equator, you may by Threads deſign the Hours, as is now a very familiar practice in making of String-Dials, which ſerve both for the Hour of the Day by the Sun, and hour of the Night by the Stars.

2. By a Plain set Parallel to the Superficies of the Glass at a convenient distance, whereon you are to design what you intend to be put on this Dial; and if the Parallel Plain be of Paste-board or Paper, a Thread fastned at the Center of the Glass, strikes your whole Dial *de morsa papyro.* The distance of the Plain from the Glass, will be as you please; *viz.* The distance of a plain from a Nodus.

3. The Pole or Perpendicular of the Glass being drawn out and designed, you can easily propound to your self, what, and in what position the Sun's rays will make an Angle of incidence with that perpendicular; and so by a Semicircle or Tangent of fine Pastboard fastned to that perpendicular, you can, on the other side, assign the like Angle for Reflection. And for the Horizon which is to be reflected, two Points may many times easily be got by the Eye, looking into the Glass, and so between the Eye and the Glass interposing a mark as by Sect. 5 two points are sufficient to design that.

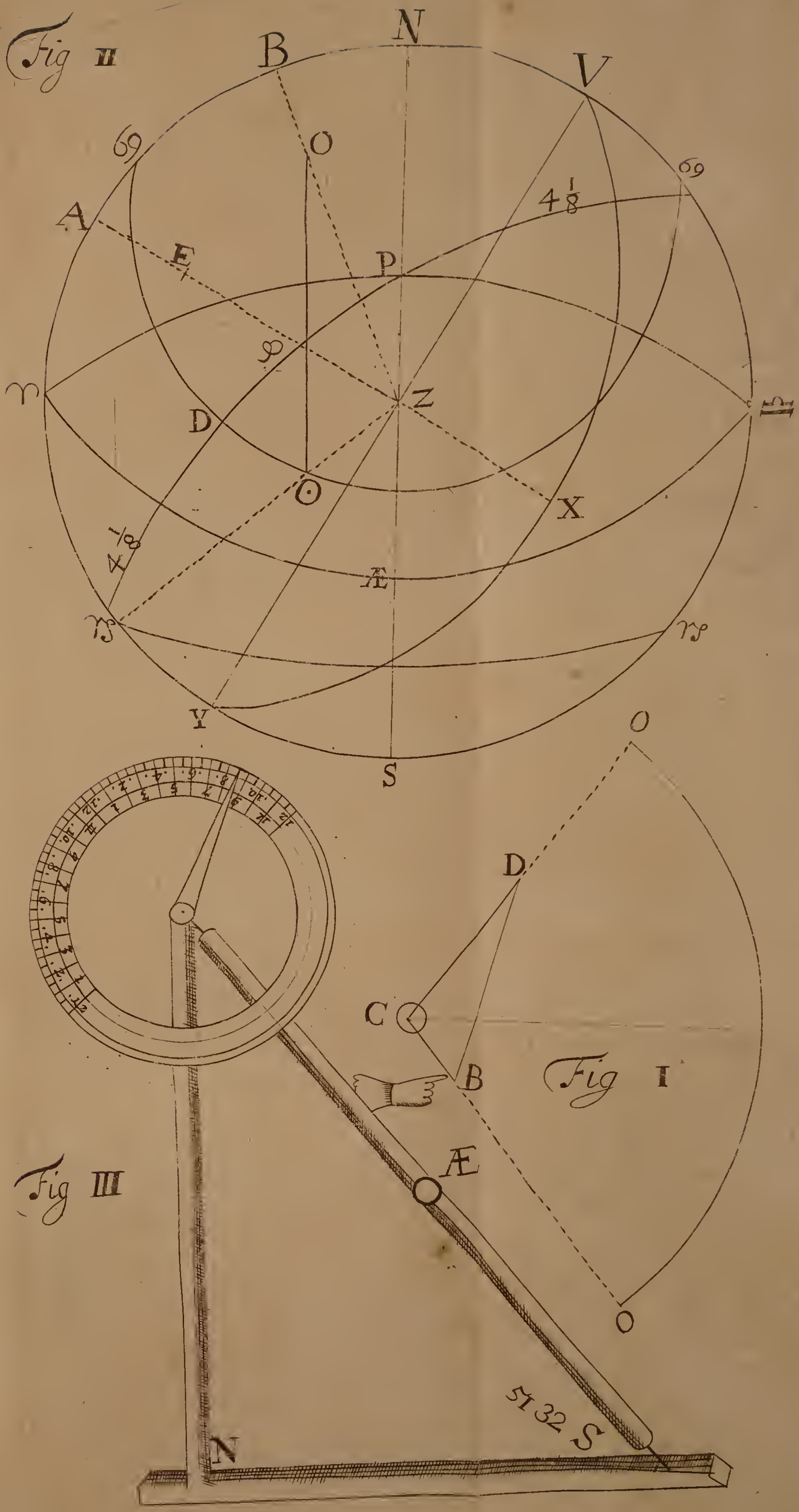
And thus by one or other of these ways you shall be sure to hit of your purpose.

POSTSCRIPT.

I Shall conclude this Tractate with the Description and Use of an Instrument, or Dial for my own Use, which by one single Hour-line designed within a Room, and that at Pleasure, (which will prevent the soiling of Hangings, Cupboards, or such like things in a Room) shall most readily give you the Hour, and actually (if your Room be large) every day in the Year. The Instrument may be of neat use in Gardens, being set near the North side of a Wall or Tower, yet so that the Sun may shine thereon, and the reflection be made in the shadow,

It is very plain and ready, and the hours upon the *Equinoctial* naturally divide themselves into $7\frac{1}{2}$ deg. a-piece, and the reason thereof (that is, the demonstration) is very apparent.

This Reflexed Dial here mentioned is no other than an Equinoctial Dial, such as is described in the XV Chap. Sect. I. Fig. X. of the First Tractate, or that in Chap. XVII. Sect. I. Fig. XVII of the same; for all are to one effect, those Plains lying parallel to the Axis of the World, and therefore the Stile lies parallel to the Plains: that is, the Plains do lie in some one Hour-circle or other. Then if the Superficies of a plain Glass (I mean the Spot designed for a Reflex Dial) be so placed, the Axis (because parallel to the Plain) will have no Incidence, and so, by consequence, no Reflection: The Perpendicular of this Glass (being an Imaginary Point) lies in the Equator: so that the Superficies of the Glass fixed in a Gnomon to turn round (now all Gnomons look into the Elevated Pole) will continually cast a Spot (the Sun shining) into some one Hour-line or other, which let be drawn at pleasure within the Room. And then fixing a small Circle with an Index to turn round, such as is the Hour-Circle of a Globe, that Index then rectified to the true Hour, when the Spot shews upon the Hour line in the Room, bringing the Spot afterwards at any time to the said Hour-line, the Index unaltered will give the true Hour.



Place this at ye End of ye XII.th Tractate to fold out.

Now why the Hours upon the Hour-Circle comprehend $7\frac{1}{2}$ degrees a-piece is very apparent. For the Perpendicular of the Reflecting Glass will always bisect the Equinoctial Arch intercepted between the Sun and the Spot (which is the Sun reflected) and so by consequence the Plain or Superficies of the Glass, moving as doth the Perpendicular, or Imaginary Point notified by the Index of the Hour-Circle, is only promoted $7\frac{1}{2}$ degrees every Hour. I need not lay down a Demonstration at large in so easie a matter, nor describe this Instrument further than I have said; the Figure III. will better inform you than many words: N S being both a Meridian and Horizontal Line, P S the Axis of the World, Æ the Glass, P the Hour Wheel fixed, but the Index moveable. *Figure III.*

" But I cease to give you further trouble at this time, desiring rather " your pardon for this confidence I take, in adding to your *Mathematical* " store, wherein, and in the right use of your other fortunes, you are *Cræso* " *ditior*. And hoping your occasions will, *&c.*

The End of the Twelfth TRACTATE.

REFRACTIVE DIALLING,

OR, OF

DIALS by *REFRACTION.*

SHEWING,

(Two Different Ways, *Viz.*)

INSTRUMENTALLY *and* PROJECTIVELY,

How to make *Sun Dials* in the inside of any *Concave Vessels* (either *Regular* or *Irregular*) and to inscribe into them all Usual *Furniture.*

Which *Dials* shall shew the true *Hour* of the Day, the *Altitude*, *Azimuth*, and *Declination* of the *Sun*: The *Jewish*, *Italian*, and *Babylonish* Hours. The Sign *Ascending*, *Descending*, and *Culminating*: The *Position* (or *Domifyng*) Circles, *&c.* When the *Vessel* shall be *quite* filled with *Water*, or when it shall be *partly Full* and *partly Empty.*

The Thirteenth T R A C T A T E.

Of Refracted Dials in General.

THE Sun Beams are refracted by any transparent Body that they fall upon, if the same be more Dense or more Thin and Rare, than the *Medium* thorow which they first shine. Such Bodies are either Solid or Liquid. In both which kinds the most Common Bodies are Glass or Christal, and Water.

Refractions (as we are here to Use them) may be divers ways considered, First in Solid Bodies, the Superficies Refracting may be either Plain or Curved, and this either truly Regular, such as is Spherical or such like, or else various of no determinate Regular Form. And likewise the Plain especially (but the other also in some sort) may be either Horizontal or otherwise placed, upright or leaning.

Again,

Again, In Solids pellucid, the Rays of the Sun from the point of an Index, ſtanding without ſide the pellucid, between the Sun and it, muſt paſs, either firſt from the Index through the Air, and then into the Solid, and ſo meeting with an apacous Body, cloſe joyned to the out-ſide of the tranſparent Body, may there be terminated, and ſo ſuffer but one Refraction at its firſt entrance into the pellucid, or elſe the opacous body (upon which the ſhadow of the Index ſtayeth and pierceth no further, but is made viſible) may ſtand at ſome diſtance from the pellucid; and ſo the Sun Rays paſs out of the pellucid into the Air again, before they come to the Opacum; by which means they ſuffer a double Refraction, one at their entrance into, the other at their going out of the pellucid Body.

All theſe Caſes are varied according as the Index and Opacous and Pellucid Bodies do ſtand.

Or further, The point of the Index may be within the pellucid, and ſo the Sun Beams muſt firſt enter into the pellucid, and ſuffer one Refraction before it comes to the point of the Index, and afterwards either meet with an opacous body, cloſe joyned to the outward Superficies of the Pellucid; and ſo ſuffer no more Refraction, but be there terminated, or elſe if the Opacum ſtand at a diſtance from the pellucid, the Sun Beams muſt again paſs through the Air, and ſuffer a ſecond Refraction (at their going out of the pellucid) before they meet with the opacous Body, or dark Superficies that ſtays them.

Or again, The point of the Index may ſtand without the pellucid, and the Sun Beams be twice Refracted through both Superficies, before they come to the point of the Index, the pellucid being interpoſed between the Sun and the point of the Index, and the point of the Index ſtanding between the pellucid and opacous Bodies.

Many Varieties beſides the Irregularity of the Opacous Bodies that are to receive the Lineaments which of themſelves are infinite.

Secondly for Water, or any ſuch tranſparent liquid; the varieties are not ſo many, becauſe the Superficies of it is always level with the Horizon; and becauſe likewiſe the liquid applies it ſelf contiguouſly to the opacus Body or Veſſel that contains it; onely beſides one fraction, the irregularity of the Veſſel that contains the Water is troubleſome. Now the refraction by Water alone can be but One, which is at the Sun Beams entrance into the Water; but the variety of projecting the Lines of the Dial is two-fold, according as the Index Point may ſtand, either within or without (that is above) the Water.

But if Water be put into a Glaſs, or any ſuch pellucid Veſſel, then may the varieties be as many as were the former of Solids, in reſpect of the ſituation of the Index, Pellucid and Opacum. Yea and more, becauſe before, the Pellucid was ſimple and ſimilar, but this Pellucid mixt or diſſimilar; ſo that the Refractions are here multiplied into four Varieties or Breaches (whereas the other had but two) *cauſa ipſius mixiones vel compoſitiones duorum Pellucidorum:* The firſt fraction is at the entrance into the Glaſs; the ſecond at the going out of the Glaſs into the Liquid; the third at the going out of the Liquid, and entrance into the Glaſs; the fourth at the going out of the Glaſs into the Air.

And thus may the Varieties be ſtill augmented by making Refractions thorow more Pellucids at once.

Now all theſe Complications of infinite Varieties, gather ſuch an incomprehenſibility, or innumerable number of difficulties in drawing hours ſo many ways, and quantities Refracted, that it will be thought to exceed the comprehenſion of humane reaſon to accompliſh it; eſpecially being ſo infinitely varied by the irregularity of thoſe Superficies that are to receive the Lineaments. If all the Caſes mentioned were intermingled, there would be no end of Varieties.

And

And becauſe the quantities of the ſeveral Refractions, at their ſeveral Incidences, are unknown, and although they were known, yet by reaſon of the irregularity of moſt Pellucid Solids, the Angles and Coaſts of Incidence would be altogether unknown, and in that regard the Refractions, both in quantity and coaſt unknown alſo. In all theſe regards it is altogether impoſſible to give any Rule, either by Calculation, or Geometrically, by drawing lines how the hours ſhould be delineated.

By the way note, That the Index muſt of neceſſity be a Point, not a Line or Axis.

In Water (indeed) where the Superficies is both a true Plain, and alſo lying truly Horizontal, the Varieties will be fewer, and ſo the Work more eaſie. But of this I will ſpeak afterward peculiarly, becauſe things neceſſary in this kind may be more vulgarly had (being more obvious) and the way much more eaſie in it ſelf, though commonly alſo thought to be exceeding difficult, being eſteemed as a rarity above the common apprehenſion and performance. And if this that is eaſieſt be ſo eſteemed of, what ſhall the former (ſo difficult) be accounted of, being involved in ſuch an innumerable number of various Varieties.

Of Refracted *Sun-Dials* in *Water*.

How to Draw them by the Semicircle *and* Planiſphere *joyntly together.*

1. THE Refractions to all Inclinations or Altitudes in Water muſt be had, as I have framed a Table for that purpoſe, which is here inſerted.

2. The Veſſel that holds the Water may be of any faſhion, regular or irregular, it matters not, but it muſt be furniſhed with every tenth or fifth Azimuth, as need ſhall be; the manner whereof in brief may be this, Set the Veſſel ſo upright as it muſt ſtand, when the Water is in it: and aſſume a Point for the South, and over againſt it (in the ſame Horizontal Level) another for the North, both oppoſite to each other in reſpect of the Point of the Gnomon, which muſt firſt of all be fixed, that is, having taken one Point for the South, in the ſame level with the Point of the Gnomon (for to it an Horizontal Line is firſt to be drawn in the Veſſel, or elſe extended by a Thread) from that South Point extend a Thread out-right over the Point of the Gnomon, which will find the North Point on the other ſide of the Veſſel. Afterwards in the Horizontal Line (drawn round about the Veſſel, or otherwiſe repreſented with Threads conveniently) by help of a Paſt-board ſet upon the Gnomons top, and by help of the North and South Points, you may project each fifth or tenth Azimuth, and make marks in the ſame Horizontal Line for each of them. This being done, by the Semicircle, find out the Zenith Point in the Veſſel, that is, apply the Ruler to the Gnomons Point, and holding it upright there, the foot of it will ſhew the Point required; for the Veſſel now ſtanding (and as it muſt be juſtly afterwards placed) in this poſture. Then laſtly, if you lay a Thread to the Azimuthal Point, and to the Apex of the Gnomon, and ſo to the oppoſite Point of each Zenith

(two

A TABLE of Refracted ALTITUDES to every Degree of the Quadrant.

True Altit.	*Refracted Altitudes.*			*True Altit.*	*Refracted Altitudes.*			*True Altit.*	*Refracted Altitudes.*		
Deg.	*D.*	*M.*	*sec.*	*Deg.*	*D.*	*M.*	*sec.*	*Deg.*	*D.*	*M.*	*sec.*
0	41	28	0	30	49	32	0	60	68	0	0
1	41	30	48	31	50	04	0	61	68	42	24
2	41	33	36	32	50	36	0	62	69	24	48
3	41	36	24	33	51	08	0	63	70	07	12
4	41	39	12	34	51	40	0	64	70	49	36
5	41	42	0	35	52	08	0	65	71	32	0
6	41	50	48	36	52	42	0	66	72	15	24
7	41	59	36	37	53	16	0	67	72	58	48
8	42	8	24	38	53	50	0	68	73	42	12
9	42	17	12	39	54	24	0	69	74	25	40
10	42	26	0	40	54	58	0	70	75	09	0
11	42	40	12	41	55	34	24	71	75	53	0
12	42	54	24	42	56	10	48	72	76	37	0
13	43	08	36	43	56	47	12	73	77	21	0
14	43	22	48	44	57	23	40	74	78	05	0
15	43	37	0	45	58	00	0	75	78	49	0
16	43	56	24	46	58	38	24	76	79	33	24
17	44	15	48	47	59	16	48	77	80	17	48
18	44	35	12	48	59	55	12	78	81	02	12
19	44	54	36	49	60	33	36	79	81	46	36
20	45	14	0	50	61	12	0	80	82	31	0
21	45	37	48	51	61	52	0	81	83	15	48
22	46	01	36	52	62	32	0	82	84	00	36
23	46	25	24	53	63	12	0	83	84	45	24
24	46	49	12	54	63	52	0	84	85	30	12
25	47	13	0	55	64	32	0	85	86	15	0
26	47	40	48	56	65	13	36	86	87	00	0
27	48	8	36	57	65	55	12	87	87	45	0
28	48	36	24	58	66	36	48	88	88	30	0
29	49	04	12	59	67	18	24	89	89	15	0
30	49	32	0	60	68	0	0	90	90	0	0

(two being always opposite one to the other, and may well go together) you may repose this Thread upon the Zenith Point lately found; so shall the umbrage of the Thread shew all along the Vessel, where the same Azimuth is to be drawn; and the same is to be done in all others. Or without Drawing or Projecting either, Threads may be fixed for Azimuths, from the Point in the Horizontal Line to the Zenith.

3. These things being thus prepared, it is left to choice whether the Point of the Gnomon shall lie always hidden in Water, or else stand above the Water. These two cases are very different, and so must be treated of in several, as two distinct Cases.

I. *When the* Gnomon *is hidden all under* Water.

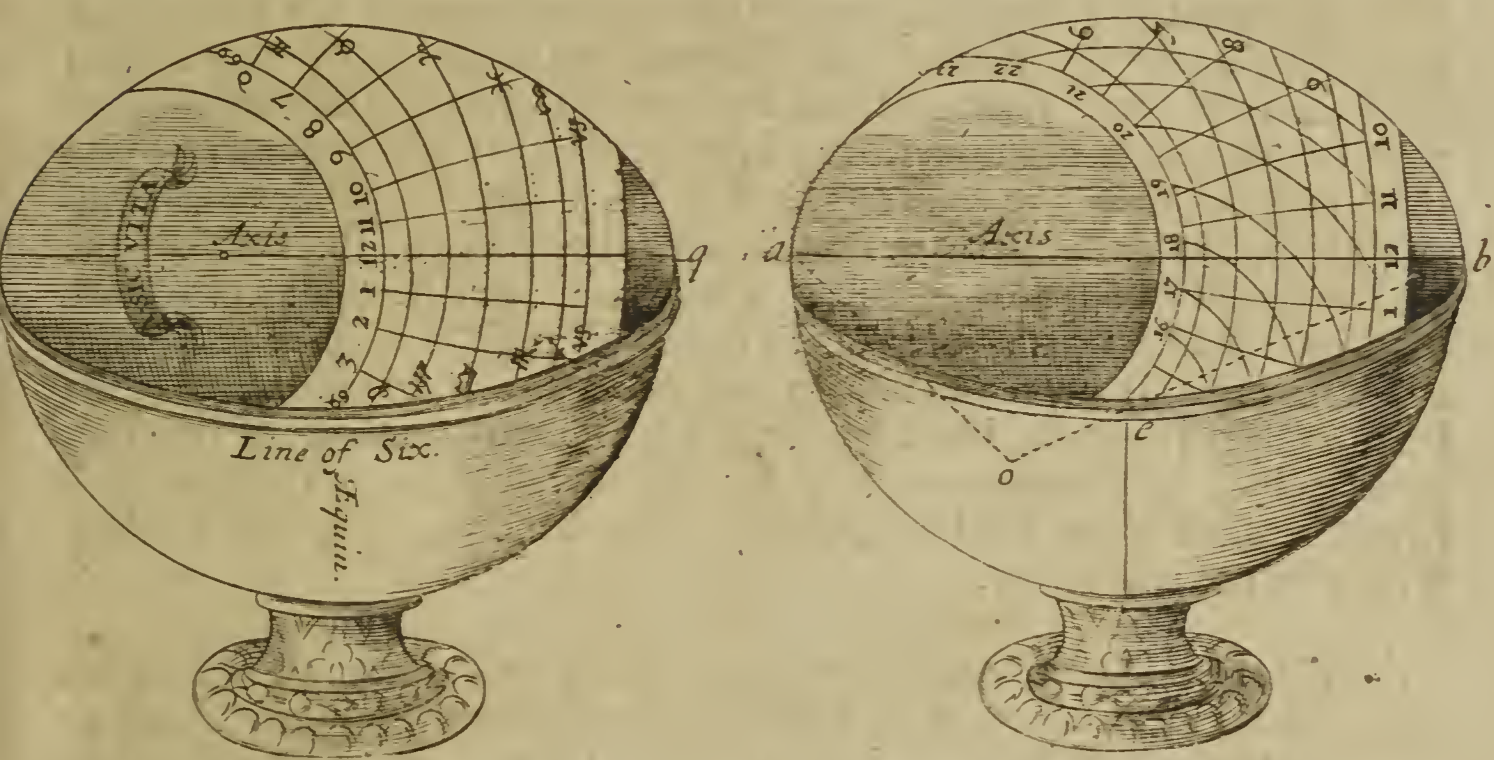
IN this case you are not tied at all how full to make your Vessel, only be sure to cover the Gnomon's Point, it matters not how much, whether more or less, for both are one. Then for the Line of 12, that is already drawn, being the same with the North and South Azimuth; but the rest must be inscribed by Points severally fixed into each particular Azimuth; the manner whereof may be thus:

Upon the Planisphere, lay the Ruler to any Azimuth (as the 60th) from the South, and there see what degree of the Ruler (or what Altitudes) each Hour Circle cutteth, and write them down in a Table.

Thus do upon every 10th or 5th Azimuth (as you shall think fit) making a Table of all those Altitudes or Intersections. Then coming to the Table of Refractors, and to each particular Altitude of the Table, find amongst the Refractions, how much belongs to each of them, and add the same to the Altitude (before found by the Projection) particularly, so shall you have turned the direct Altitudes into refracted ones.

After all this, come again to the Vessel, and with the Semicircle insert each particular Refracted Altitude into his proper Azimuth where it belongeth, so shall you have points in each Azimuth, for so many Hours as the same Azimuth is capable of. Having then these helps, through each Point belonging (in every particular Azimuth) to the same Hour, as suppose the Hour of 9, draw one continued curved Line, which must serve for the Hour of 9 a Clock, so through all the Points in every Azimuth, serving for 8, draw one continued Line, which must in like manner serve for the Hour of 8 a Clock; and so do for all the rest. The Horizontal Line will be about 37 deg. below the Point of the Gnomon, so much, namely, as the Horizontal Fraction cometh unto; and up to this Horizontal Line (and not any higher) must the curved Hour Lines be drawn. The Coasts North and South will be opposite (in the Vessel) to those of the Heavens, in the same manner here as they are in other Dials. This work cannot be done by projecting the Hours, with help of an Axis, as in other Projections; for neither the Rays from the Eye can possibly fall upon the Water to project in the same manner that the Sun Beams do (which in direct Projections is not requisite, but in Refracted it is) nor the projection made by the Sun Beams themselves (though of the same Hour Circle) will be the same in fashion, the Sun standing in several positions to make this projection, as in one instance (in a right Sphere) will sufficiently appear;

pear; for in a right Sphere the Axis (as all know) muſt lie parallel to the Horizon, or Superficies of the Water; and the Hour of 6 will be the ſame with the Horizontal Line. If therefore we ſuppoſe ſuch an Axis in a round Spherick Concave Veſſel, full of Water, to be laid from the one ſide of the Veſſel to the other, and the Sun to riſe or ſet in the Equinoctial which is proper to the Axis; then ſhall the Hour of 6, or the one half of the Horizon, be projected, dipping down (from each point of the Axis, projected by the Parallel Rays of the Sun) ſo much as the Horizontal Refraction comes to (about 37 deg.) whence it muſt follow, that this Projection of the Horizon muſt dip moſt under the Axis in the Projected Equinoctial Circle, and nothing at all under the two ends of the Axis, which concur with the ſides of the Concave Veſſel; whence the Sun, being in the Equinoctial as we now ſuppoſe it to be, the Axis and Horizon, or 6 a Clock Line in a round Veſſel, would appear thus, as in the Figure.



But again, If the Sun being out of the Equinoctial, as in one of the Tropicks, and there be ſuppoſed to riſe and ſet, then ſhall the Horizon, or Hour of 6, be projected ſo by the Sun, as that a Ray from the Sun upon the middle Point of the Axis, ſhall project the Horizon in the loweſt Point; which loweſt Point will be in the projected Tropick, and not in the Equinoctial, as the former Projection was. So that now the Axis and the Line of 6, will appear in the ſame Veſſel, in the form of *a o b*, whereas before it was like *a e b*; whence firſt it is evident, that an Axis cannot project (in all Poſitions of the Sun, to the Axis and Water) one ſingle Line for each Hour, as they ought to be; and therefore that way by an Axis is in this work to be rejected as unſerviceable.

Secondly, It follows alſo, that (though the Sun ſhould (by reaſon of infinite remoteneſs) make requiſite Lines, yet) the Eye cannot in this kind perform what the Sun doth; becauſe it being always near to the Superficies of the Water, doth receive diſtances from ſeveral parts of the ſame Superficies of different quantities, great and leſſer; and ſo the Rays paſſing from the Eye, do make ſeveral Angles of Inclination, and conſequently ſeveral Refractions, which the Sun by his immane di-

ſtance

ſtance doth not, but is thereby freed from it; ſo that the Hour Lines cannot be projected (by help of an Axis) with the Eye in the ſame faſhion that the Sun requires; nor yet if they could, would they be of any uſe, as is before ſaid. Thirdly, Again it follows, that a point only (and not a Line, or part of the Axis) is to be uſed for a Gnomon. Fourthly, That the inſcription of the Hours muſt needs be done by finding certain Points, thro' which they are to be drawn. One way of which Protraction is now delivered; this former way ſuppoſeth the Refractions to be ſingle upon a Meridian, lying in a Horizontal level, and to be known alſo according to all inclinations.

How to make the Hours cloſe right with the Horizontal Circle.

YOU muſt firſt draw the Refracted Horizontal Circle, which is all one as if you would draw the 37 deg. Almicanter (for about 37 deg. is the Horizontal Refraction; and ſo much therefore muſt the Horizontal Circle dip under the point of the Gnomon in the Water) ſo that I need ſay no more of that: Then may you divide this Horizontal Circle into ſuch parts or degrees, as the ſpaces of an Horizontal Dial will require and into thoſe diviſions muſt the ends of the Hour-lines run. Alſo above this Horizontal-line nothing needs be drawn, for it is of no uſe, the Point of the Gnomon will never grow higher. Likewiſe it will be moſt convenient to fill the Veſſel with Water up to the brim in this caſe here propounded, where the Gnomon lies hidden under Water; and ſo alſo to make the brim 37 deg. (at moſt, but fewer deg. is beſt) above the Point of the Gnomon; which your Semicircle will do: for by theſe means the Sun ſhall have free acceſs to the Dial ſo long as it is above the Horizon, which otherwiſe will not poſſibly be.

And here Note, that if the Refracted Altitudes be inſerted into my Semicircle out of my Table of Refractions in Water, and ſo made into a Scale or Limb; if this (I ſay) be done, then may you immediately (without turning your direct Altitude into refracted, according as is preſcribed in the precedent page) put in the ſame things in the ſame manner and quantity, if you count theſe Altitudes in your Refracted Scale (and not in the common limb) and accordingly do inſert them all, your Thread and Plummet hanging upon the Altitude taken into the ſame Scale; ſo will the former labour of turning one into the other be taken quite away. And ſo much will ſerve for this firſt Caſe, when the Gnomon is quite covered under Water. The Second follows, which is,

II, *When*

II. *When the Point of the* Gnomon *ſtands above the* Water.

1. THE Gnomon being ſet, and the Veſſel fitted (as is before preſcribed) with Azimuths convenient, you muſt ſet the Veſſel upright, according to the ſelf ſame poſture that you intended it ſhould have when it is fitted with Water, and in that ſituation let it be fixed, till your Work be done at the leaſt.

2. Next you are to conſider how high you will fill it with Water, for to that Altitude you muſt draw an exact true Horizontal line upon the ſides of the Veſſel, the very ſame that the edge, or Superficies of the Water will make when it is filled up to it: This is neceſſary to be done, firſt, as alſo you muſt draw another Horizontal line about the ſides of the Veſſel, which muſt be *in æquilibrio* with the Point of the Gnomon, and this will be (moſt conveniently) the very edge of the Veſſel, that ſo the Sun (all the time that it is above the Horizon) may have acceſs to the Gnomon's Point, and ſhew the Hour too; both which cannot be, unleſs the Veſſel's brim be juſt in Equilibration with the Gnomon's Point.

3. Between this brim of the Veſſel, and the Water Horizontal Line is part of the Dial to be drawn by direct Projection; and below this, namely where the Water filleth up, is to be drawn the reſt of the Dial by Refracted Projection; and accordingly we are to give diſtinct Rules for both.

4. For the upper part, it may be deliniated either by the Horizontal Planiſphere, and the Semicircle, or elſe by projecting it with an Axis.

I. *By the Planiſphere.*

YOU may find what Altitudes are due to every Hour upon every Azimuth, and by the Semicircle you may put them into the right Azimuths, and ſo from point to point, draw the Hour lines till you come down to the Water Horizontal Line; and for the upper ends of the Hours, to make them fall true into the brim of the Veſſel, you muſt do as before in the former Work was done; that is, you muſt deſcribe (in the brim or Horizontal Line of the Dial) the ſpaces of an Horizontal Dial, and in thoſe Points or Spaces muſt the Hours begin to iſſue forth. So again for the lower ends of the direct Hour Lines, to find the very points into which they are to run upon the Water Horizontal Line, the Work will be either harder or eaſier, according as the Veſſel, and ſtanding of the Gnomon, are Regular or Irregular — For if the Veſſel be round, and the Point of the Gnomon do ſtand juſt in the Center of it, then it will be eaſie to do it, for then the Water Horizontal Line is a true Almicanter; and by your Semicircle you may know what Almicanter it is. If accordingly therefore you conſider upon your Planiſphere how many degrees of that Almicanter are comprehended between 12, and each Hour, and inſert the ſame ſpaces or degrees into the ſame Almicanter or Water Horizontal Line, thoſe

Points ſhall be the Terms of the Hours into which they muſt come. But if the Veſſel be not Regular, or though it be, if the Situation of the Gnomon be not Regular to it, then it will be difficult; and indeed ſo difficult, that it is not *operæ pretium* to uſe it, I will refer it to this next Projective way of putting in this Superior part of the Hours, which will perform this thing eaſily. But by the way, after you have inſerted the one part of the Hour Line, by drawing it as I now ſhewed, you may continue it whither you will by Projection, as I have heretofore ſhewed; and ſo you may continue it downward unto the Water Horizontal Line.

II. *By Projection.*

THIS is done in the ſame manner that I have often heretofore ſhewed, either by an Axis and Horizontal Points, or elſe by the Equinoctial Points, and for theſe you need draw no Azimuths; or elſe by Azimuthal Points, put into two Azimuths, which only are neceſſary to be done: I need not make Repetition of it here again. So then the upper part of the Dial above the Water is deſcribed.

The lower Refracted part which lies within the Water may alſo be done two ways; either by the Planiſphere and Semicircle: Or elſe by Projection alone.

I. *By the Planiſphere.*

SEEK how much each Hour is elevated upon every ſuch Azimuth as is deſcribed in the Veſſel, and by your Table of Refractions turn it into Refracted Altitude, as was before ſhewed; ſo theſe two Altitudes may be called, The Firſt, The Direct, and the Latter, the Refracted Altitude. Or when you come to inſert theſe by your Semicircle, for the Direct Altitudes you may count them upon that Limb which is divided into equal degrees, and the Refracted Altitudes you may inſert by that Limb which is made for Refracted Altitudes by Water. And ſo you muſt underſtand me when I bid you to put in the Direct Altitude and the Refracted Altitude, that is, to count the ſame Altitude in the Direct, or equally graduated Limb, and in the Limb of Refractions, and ſo ſhall you need no Table of Refractions, becauſe this new inſerted Limb performs the uſe of the ſame Table immediately, without any turning of one Altitude into another. Both Altitudes we are here to uſe. Firſt, We ſuppoſe the Veſſel ſet as it muſt ſtand when it is filled with Water, and in this ſituation look what Azimuth you mean to deal with, or into which you intend to inſert the Hour points, from the ſame Azimuth noted in the Water Horizontal Line, and in the true Horizontal Level, and juſt alſo under the Point of the Gnomon, which is to ſay juſt in the Zenith Line (or from the Azimuthal Point in the Water Horizontal Line to, or directly towards the Interſection of the Water Horizontal Plain with the Zenith Line) ſtretch a Thread, and (having firſt put upon it a Bead that may ſlip up and down, or elſe a Slipping Knot may be put on afterwards) there

faſten

faſten it. After this is done, by help of the Semicircle applied to the Point of the Gnomon, put upon that Thread (as being the Azimuth) the Direct Altitude which you mean to inſert, and thereto ſlip the Knot or Bead; then again from this Bead down unto the ſame Azimuth drawn upon the Veſſel ſides, project (with your Semicircle or Rulers edge applied thereto) the Refracted Altitude, and there make a Mark; for in that mark muſt the Hour (whoſe Altitude you now inſert) run, the ſame Work you are to do for all the Hours and their Altitudes that paſs thorow this Azimuth; and the like muſt be done in other Azimuths alſo for the ſame Hour Points. Then laſtly, Having found Points for every Hour, you may thorow thoſe Points draw the Hour Lines, and ſo finiſh the Dial in every particular.

II. *By Projection.*

BUT now the Veſſel muſt be filled up to the Water Horizontal Line, and be in all Points fitted as when it is really to ſhew the Hour of the Day; and being ſo prepared, you ſhall need to inſcribe no Azimuths at all into the Veſſel; but as in other Projecting of Hours, ſo here do thus: Make two Points for North and South, and ſet the Hour Points upon the Brim of the Veſſel which you take to be *in æquilibrio* with the Gnomon's Point (however put thoſe points into the Horizontal Line, which is *in æquilibrio* with the Gnomon's point; or if there be none drawn in the Veſſels, ſet Threads there round about it, as the manner of other Dials hath been, and into them inſert Knots or Hour points) and erect an Axis as in other Dials: Then project (as you uſe to do) the Axis upon thoſe points, and with ſome File or Dent make a Mark where the point of the Gnomon is repoſed thorow the Water upon the ſide of the Veſſel which Mark ſhall ſerve for one point thorow which to draw that ſame Hour. Then removing your Eye a little higher or lower, ſtill repoſe the Axis upon the ſame Hour point, and mark again the place upon which the point of the Gnomon ſeems to lie; for this alſo will be another point thorow which the ſame Hour is to be drawn. Thus remove the place of your Eye ſo often, and do the ſame Work over, untill you have found points ſufficient to finiſh the draught of the whole Line. In the ſame manner you muſt find points, and thorow them draw each of the other Hours. This kind of Work is neceſſary for that part of any Hour which lies under the Water; but for the part above the Water, that is projected at one view, as hath been before ſhewed; for that not going down into the Water at all, is freed from Refraction. Remember alſo that the Axis muſt always go above the Gnomon's Point, and keep in the Air, but at no hand go down into the Water. To the Water it may go, and be faſtned below too in the Water; but my meaning is, you muſt not then project by that part of it which is within the Water, becauſe the Refraction will deceive you. And be careful that the projecting part of the Axis (namely all that which lies above the Water) do lie at the true Elevation of your Pole, and that you project only by that ſame part. And thus have we finiſhed theſe two Caſes, which were to ſhew, How to draw Hours in a Veſſel of Water, where the Gnomon lies within the Water, or where it ſtands above it. Now if beſides the Hours, any ſhall in theſe two Caſes, deſire

To put in the other Furniture.

THEY may in brief do it thus: It must be remembred that all Furniture is to be put in by the Planisphere and Semicircle, as I have already shewed. And that all things that way are put in by Altitudes, such as in each kind the Planisphere will help unto. The very same manner of Work is here again to be used, only in the first case you must altogether use Refracted Altitudes, and in the latter case, you must use both Direct and Refracted Altitudes, one after the other.

For the first Case then it will be as easie as if you were to work in the way heretofore taught by the Planisphere, applying the Ruler of the Semicircle to the point of the Gnomon and to the Hours, only you must remember to count all your Altitudes in the Refracted Limb of the Semicircle, and not in the common Limb of Equ. degrees, because all, both Gnomons point and Hours are under Water. And this will be enough to admonish concerning the first Case, where all things are totally refracted: Or you may put all in by the Semicircle, projecting upon the Azimuths, not Hours, as follows in the other way. Then again, in the second Case, where the Work is partly direct and partly refracted, so much of your Work as is above Water. may be furnished with direct Projection, as hath been shewed heretofore in the use of the Planisphere and Semicircle. But for the other part which is below in the Water, there are several ways to be used, but the best will be to project all upon the Azimuths that were at first prescribed to be drawn upon the Vessel sides; and so all will be easie, whereas otherwise they will be very hard. Having then by the Planisphere found such Altitudes upon the Azimuths as are requisite, you are then prepared to put the same in; but it must be by using the same way that was before put in practice for the Inscription of the Hours; namely this: Let your Vessel have no water at all in it, but yet set true, as hath been before prescribed. Then from any Azimuthal point in the Water Horizontal Line, to the Intersection of the Water Horizontal Superficies with the Zenith Line falling from the point of the Gnomon, stretch out a Thread and fasten it there, and upon it let be put a slipping Knot or Bead. Then look what Altitudes you have to put in (for Parallels of the Equinoctial or Almicanters, or Sections of the Ecliptick with the Azimuths, or any such like) the same must be put into the Thread first, by applying the Ruler of the Semicircle to the Gnomon's point, and fitting it up, till (the side of it also touching the Thread) the Plummet hang at the direct Altitude of the equal Limb, then to that point of the Thread where the edge of the Ruler crosseth it, slip your Knot and Bead, afterwards again, apply the Edge of your Semicircle to this Knot, and keeping it still there close to it, lift it up till the Plummet and the end or point of it keep also in the Azimuth whereto the Thread is annexed; that part of it, I mean, which goes up to the side of the Vessel into the Water: so shall the end or point of the Ruler, give you the point of the Refracted Altitude required. Thus do till you have found all the points of such things as you mean to put

upon

upon that Azimuth, and then go to another Azimuth, and do ſo there too, until you have done as much as you deſire. Then laſtly, thorow every correſpondent point draw ſuch Lines as you require. This is the ſum of what is to be done in this Caſe.

And Note here, That if it be ſo, that then Altitudes of ſome things cannot be had upon the Azimuths by the Planiſphere (ſuch as are thoſe things that concern the motions of the Eclipticк) in ſuch a Caſe you may (by the Planiſphere) find in what part the Ecliptick cuts any Hour Circle, as is ſhewed before in the uſe of the Planiſphere; and thereto apply the Ruler of the Planiſphere, which will ſhew you in what Azimuth this ſhall happen: this Section (I ſay) of the Ecliptick with the ſame Hour. If now you put in the ſame Azimuth into the Horizontal Line, and project it into the Veſſel, you ſhall find the ſame point of interſection with the Hour, and thorow that point muſt the Ecliptick Circle paſs. The like may be done for all the other points of Interſection. And this you may do, without finding what Altitudes the Ecliptick hath upon any Azimuth; which I believe the Planiſphere will not do very well. Therefore in ſuch Caſes this Direction may be ready, or elſe take that way which is adjoyned to this if you think not much of your labour, whereto that way will put you.

This way I have given as the beſt, but I fear the Planiſphere will not do (as I ſaid) his part. I have now added the Water, to help forward the buſineſs; and that all may be the better known and underſtood at leaſt, I will add another Direction here, which every one may refuſe or uſe at his pleaſure, as he ſhall like: And this is projectively without the Planiſphere. Therefore now again fill your Veſſel with Water as full as it muſt be, and having the Axis and the Hour points found and placed as even now they were, you may on the projecting ſide (that is on that ſide on which you do ſtand when you project any point from the Gnomon to the Veſſel, or on that ſide which the Sun is on when it caſteth his ſhadow) from ſome ſuperiour point of the Axis (or from the Supreme point of the whole Axis) ſtretch out a Thread, and with your Eye repoſe it and the Axis and the point of any one Hour, all three in one; and in that ſame poſition faſten your Thread; this done find upon this Hour (by your Planiſphere) ſuch Altitudes as you require, and from the Gnomon s point inſert them into the new faſtned Thread by help of your Semicircle, and there tie Knots upon the ſame Thread for Marks: Then come to project the ſame Knots, which is done by repoſing with your Eye thoſe ſame Knots upon the point of the Gnomon, and in that poſition both theſe points will be repoſed alſo upon the ſides of the Veſſel within the Water. Obſerve therefore where theſe Points are repoſed by the Eye, and upon the Veſſel ſides (with ſome Bodkin or Dent) make a Mark; for that muſt be the projected Point, anſwering to that upon the Thread from whence it was projected. In the ſame manner are the other points to be projected and marked, and ſo you are to deal with other Hours

too, only for each of them you muſt place a new Thread, and furniſh it with Knots, as before was done. This may ſerve for Direction in this way. Other ways a man may find out of himſelf as neceſſity ſhall put him to it, and therefore I will mention no more here.

As concerning Azimuths, it may be obſerved that they only of all other Circles, ſuffer no Refraction by Water, becauſe they all ſtand perpendicularly to the Superficies of it; and therefore they are already put in as is preſcribed in preparing the Veſſel for the reſt of the Work, both for Hours and other Furniture: for in both theſe their help is requiſite. But when all Inſcriptions are made, if they prove cumberſome to the reſt of the Work, by filling it over-full; they may then in ſuch Caſes be wiped out.

The End of the Thirteenth TRACTATE.

OF THE FIVE REGULAR, OR, PLATONICK; (and of other *Polyhedron*) BODIES.

The manner how to Cut *them in* Wood *or* Stone, *and to Furniſh them with* Sun Dials.

The Fourteenth TRACTATE.

CHAP. I.

Of the Five Regular (or Platonick) Bodies.

IN this Tractate I ſhall ſhew the manner how to cut theſe Five Regular Bodies in *Stone* or *Wood*, and what *Dials* will ſerve to furniſh each *Body:* With *Tables* of all the *Requiſites* and *Hour Diſtances* belonging to each *Dial:* With the *Chapters* in this Book which ſhews the making of the ſame. Alſo the deſcription of another *Regular Polyhedron*, or Body conſiſting of Plains of ſeveral Sorts, as *Triangles*, and *Squares*, intermixed: Their *Declinations*, *Reclinations* and *Inclinations:* All which Bodies I ſhall here ſhew how to deſcribe upon fine *Paſtboard*, *in plano*, the vacancies whereof being cut away, the Plains repreſenting the *Body* ſhall remain; and theſe being joyned together by the edges, with Glew, ſhall compleat the *Body*, as if it were cut in *Stone*; Upon each of which Plains, you may draw the *Dial* proper for the ſame, and cut *Stiles* of Paſtboard, fixing them in their due place; And by this means your fancie will be much informed concerning the harmony there is between the Dials of ſo many ſeveral *Plains* upon one *Body*; as to ſee the *Stiles*, all of them, to be *Parallel* one to another, and to point directly to either of the *Poles* of the World, &c.

For

For Instance Then:

THE Five Regular (or *Platonick*) Bodies are, 1. The *Hexaedron* or *Cube*, 2. The *Tetraedron*, 3. The *Octaedron*, 4. The *Dodacaedron*, 5. The *Icosaedron*: To which I shall Add, 6. The *Canted Cube*; or *Hexicosaedron*,

CHAP. II.

Of the Hexaedron *or* Cube.

Figure I. THIS is a Solid Body consisting of six Sides, Plains or Bases, each being a Geometrical Square, and it also containeth Eight Solid Angles.

I. *How to Cut this Body.*

I Need not spend time in giving any directions for the cutting of this Body in Stone or Wood, it being a Body so well known to all Artificers and others; for it is no other than a Piece of Wood or Stone, cut exactly in the form of a Gaming Dye.

The manner how to cut this Body out in Pastboard is discovered in Figure I.

Of the Dials *that will Furnish this* Body.

THIS Body is capable to receive Five Dials, the sixth Side being the Base or Foot upon which the Body standeth: And so, if you set any one side to behold the *South*, that Plain shall be capable to receive the *South* Dial and the side opposite thereunto a *North Dial* whose descriptions, Figures, and Table of Hour distances you shall find in Tractate I. Chap. X. Fig. II. and III.

The other two Sides shall be capable to receive, one an East, and the other a West Dial, The Descriptions, Makings and Figures, are described in Tractate I. Chap. XI. Fig. IV and V.

The Uppermost Plain will be capable to receive a *Vertical* or *Horizontal Dial*, whose Description, making and Table of Hour distances you shall find in Tractate I. Chap. IX. Fig. I. So that I shall need to say nothing more of them in this Place—Thus if you will set one of the Sides of the *Cube* to behold the South; But----If you will have one of the Angles of the *Cube* to look towards the South: Then the 12 a Clock Hour line of the *Horizontal Dial* must be drawn on the uppermost Plain from Angle to Angle: And then will the four upright Plains be *North* and *South Decliners* towards the East and West 45 deg. which Dials must be made by the directions and cautions given in Tractate I. Chap. XII and XIII. and Fig. VI. But because the Examples and Tables in the XII and XIII. Chapters are not made for North and South Plains declining 45 deg. (as these belonging to this Body do,) but for 30 deg. and 35 deg. I shall therefore here insert a Table of the *Requisite Hours*, and *half Hours distances* belonging to North and South Plains declining 45 deg. suitable for this Body.

South

South and *North* declining.	45^d .	00^m
Height of the *Pole* or *Stile*	26 .	06
Deflection.	29 .	20
Plain's Diff. of *Longitude*.	51 .	57

Hours and halves from the Substile.		*Hour Distances upon the Plain.*	
Substile		0^d	00^m
9	3	3	4
half		6	28
10	2	10	3
half		13	57
11	1	18	18
half		23	20
12		29	20
half		36	42
1	11	45	57
half		57	41
2	10	72	11
half		88	46

Hours and halves from the Substile.		*Hour distances upon the Plain.*	
Substile		0^d	00^m
half		0	15
8	4	3	34
half		6	59
7	5	10	36
half		14	33
6	6	19	0
half		24	9
5	7	30	19
half		37	55
4	8	47	30
half		57	38
3	9	74	31

The Figure of this Body as a Solid, is described in *Figure* I. and as it may be cut out in Pastboard also. In which

The Plain A, B, C, D, E, F is to have upon it:

- A — An Horizontal Dial.
- B — A South Dial.
- C — A North Dial
- D — An East Dial.
- E — A West Dial.
- F — The Base or Foot.

If you set one of the sides to behold the *South*.

But if one of the Angles behold the South: then,

The Plain A, B, C, D, E, F is to have upon it:

- A — An Horizontal Dial.
- B — A South Dial declining East 45*d.*
- C — A North Dial declining West 45
- D — A North Dial declining East 45
- E — A South Dial declining West 45
- F — The Foot or Base.

CHAP. III.

Of the Tetraedron.

THE *Tetraedron* is a Solid Body, containing four Bases, and four Solid Angles, each Base or Plain being an *Equilateral Triangle*. *Figure* II.

I. *How to Cut this Body in Wood or Stone.*

ON any Rough piece of Stone or Timber, make one side Plain and Flat; upon which I describe an Equilateral Triangle so large as the Plain is capable of: Then set a Level, (or cut a Templet in Wood) to

70 deg. 31 min. 42 ſec. And Plain another ſide of the Piece to fit both the other ſide and the Level, making his Second ſide as the former. Then cutting away the reſidue of the Wood or Stone, and planing the Plains even by the Stroaks or Marks, you ſhall have conſtituted the *Tetraedron* required.

The Figure of this Body, as it is a Solid, and alſo as it is to be delineated upon Paſte-board, you have in Fig. II.

II. *Of the Dials that will furniſh this Body.*

MAKE any of the Sides the Baſe, as G in Fig. II. then will the other three Plains each of them Recline 19 deg. 28 min. 16 ſec. And if the Angle at *a* be ſet towards the South; the Plain F will be a direct North Plain, Reclining as before; and the Dial will be made by the directions in Tract. I. Chap. XVI. Fig. XIV.

The other two Plains will be capable of two other Dials, *viz.* K will be capable of a South Dial declining Eaſt, and C of a South Dial declining Weſt 60 deg. and Reclining 19 deg. 28 min. 16 ſec. One Dial will ſerve for both theſe Plains, and are to be made according to the directions and Figure belonging to the ſecond Variety, in Tractate I. Chapter XVII. and Figure XVIII. The Requiſites and Hour diſtances belonging to which Dials are in the Tables following.

	d	′	″
North Re.	19	28	16
Stiles h.	57	56	16

Hours and halves from the Merid.		Hour diſtances on the Plain.	
		0d	00m
12		0	00
half		6	22
11	1	12	48
half		19	21
10	2	26	4
half		33	2
9	3	40	17
half		47	50
8	4	55	44
half		63	57
7	5	72	27
half		81	10
6	6	90	00

	d	′	″
South Reclining.	19	28	16
Declining Eaſt and Weſt	60	00	00
Diſt. between Merid. and Hori.	60	00	00
Arch between Plain and Zenith	35	15	52
Height of the Stile	1	50	53
Deflection	2	36	56
Differ. of Longitude.	54	46	43

Hours and halves from the Subſtile.		Hour diſtances on the Plain.	
Subſtile		00d	00m
half		0	4
9	3	0	19
half		0	35
10	2	0	52
half		1	10
11	1	1	32
half		2	0
12		2	37
half		3	31
1	11	5	0
half		8	8
2	10	19	26

Hours and halves from the Subſtile		Hour diſtances on the Plain.	
Subſtile		00d	00m
8	4	0	10
half		0	25
7	5	0	41
half		0	58
6	6	1	18
half		1	42
5	7	2	13
half		2	55
4	8	4	0
half		5	56
3	9	10	16
half		29	2

CHAP.

CHAP. IV.

Of the Octaedron.

THE *Octaedron* is a Solid Body containing eight Bases and six Solid Angles; each Base or Plain, being an Equilateral Triangle. *Figure* III.

I. *How to Cut this Body in Wood or Stone.*

PRovide a *Paralellipipedon* (or Long Cube) If the breadth both ways be 1000. let the Length be 1.414: Or if the Length be 500000, the Breadth both ways must be 3.53553. Square the Piece to these Measures Exactly, and divide the Length and Breadth just in the middle; then draw Lines both ways at all the six Sides; and also the Diagonal Line from the midst of the Length to the midst of the Breadth: Then cutting away the Waste by these Diagonal Lines, and the *Octaedron* will be finished. The Figure of this Body as it is a Solid, and also as it is to be cut out in Pasteboard you have in Fig. III.

II. *Of the* Dials *that will Furnish this* Body.

THE Body being thus prepared, Let the Angle of that which you set for the Horizontal Plain, be towards the South; and then the same Dials which furnished the *Tetraedron* will serve this Body also: For one shall be a South Inclining, and his opposite a North Reclining 19 deg. 28 min. 16 sec. And the two South declining 60 deg. and reclining as before, will have their opposite North Declining and Inclining as much; So the Dials and Requisites being the same as in the foregoing Tables, it were needless here again to repeat them.

So in Figure III. If you set the Angle * of the Horizontal Plain P to behold the South: Then,

The Plain		will be a		
	S	South Plain Inclining	19d 28' 16"	
	M	North Plain Reclining		
	O	South declin. East	60d and Reclining	19.28.16
	Q	South declin. West		
	N	North declin. East	60d and Inclining	
	R	North declin. West		

Figure IV.

CHAP. V.

Of the Dodecaedron.

THE *Dodecaedron* is a Solid Body consisting of twelve Sides, and twenty Solid Angles, each Base being an Equilateral Pentagon.

I. *How*

I. *How to Cut this Body in Wood or Stone.*

TAke a Piece of Round Stone or Timber, and if you make the Diameter thereof to be 100000, then the length thereof must be 0.81005, Or the proportion of the Diameter to the length of the Cylinder, must be, as 4.906 to 3.973 : This Piece being now a perfect Cylinder, exactly Turned, and the ends Plained : divide the Circumference of the two ends into 10 equal Parts, and by these Divisions draw Perpendicular Lines from Division to division at either end, along the Cylinder, Hewing or Planing away all the Stone or Timber that is between Line and Line ; so will your Piece be a Solid of 10 equal Sides.

Then making the whole Diameter of the Circle at that end of your Cylinder to be 1.000. take 0.309 of those Parts in a pair of Compasses, and with that distance on the Centers at each end of your Piece, describe two Circles ; and if from Angle to Angle, (each to his opposites) of your ten sided Figures at each end, you draw Lines, those Lines shall give you Points upon the two little Circles whereby to describe two *Pentagons*, which will be two of your *Pentagonal Plains*, Equal and Parallel to each other.

These two sides or Plains thus prepared ; for the other 10 Plains do thus : Divide the length of your Cylinder into 1.0000 equal Parts, and take out of them 0.3821, which distance set from the two ends of the Piece, upon the 10 Angles of the Piece ; and draw Lines from Point to Point round about the Piece ; so will there remain (of the length of the Cylinder) between these two Lines drawn about 0.2358 parts of the former 1.0000. Lastly, Lines drawn Diagonally upon all the 10 sides of the Piece will direct you what to cut away, and to compleat your Body : The exactness whereof you may examine by cutting of a Bevel or Templet to an Angle of 116 deg. 33 min. 54 sec.

The Figure of this Body as a Solid ; and also how to be described upon Pasteboard you have in Fig. IV.

II. *Of the Dialls which will furnish this Body.*

THIS Body consisting of 12 Plains, hath one of them for its *Base*, and the opposite Plain thereto will be capable to receive an *Horizontal Dial*, as the Plain P in Figure IV. Then if you will set the Angle ⊙, of the Plain P, to behold the South, Then shall there be about that Horizontal Plain five other Superiour Plains namely the Plains T V W X and Y, each of them Reclining 26 deg. 33 min. 54 sec. and opposite to them five inferiour Plains, namely, Z Æ A B C inclining as much, namely 26 deg. 33 min. 54 sec.——The Angle ⊙ of the Horizontal Plain P, being set to behold the South as aforesaid, And then,

The Plain	X	shall be a	North Plain Reclining		d. m. sec. 26 · 33 · 54
	T		South declin. East	36 *d* and reclin.	
	V		South declin. West		
	W		North declin. West	72 *d* and reclin.	
	Y		North declin. East		

And

And the five inferior Plains Z Æ A B C oppoſite to theſe Superiour Plains ſhall Incline and Decline anſwerable to the five Superior; ſo that the ſame Dials will ſerve for both Faces, the Requiſites belonging to them with the true Hour diſtances, are exhibited in the three following Tables.

N. Re. S. Incl.	26d. 33'. 54''	
Stiles h.	65. 1.54	
Hours from the Merid.	00d	00m
12	00	00
half	6	48
1 11	13	39
half	20	35
2 10	27	38
half	34	49
3 9	42	12
half	49	41
4 8	57	30
half	65	00
5 7	73	32
half	81	44
6 6	90	00

(Hour diſtances on the Plain.)

	d	'	''
North Recl. 26*d.* and Decl. 72*d.*			
Arch of the Plain between the Meridian and Horizon.	36	0	0
A. of the Me. betw. Pl. and Zenith.	58	16	57
The height of the Pole or Stile	31	28	20
Deflection	82	4	40
Differ. of Longitude.	85	50	41

Hours from the Subſtile. *Subſtile*	00d	00m	*Hours from the Subſtile* *Subſtile*	00d	00m
6 6	2	10	half	1	42
half	6	9	5 7	5	43
7 5	10	17	half	9	49
half	14	41	4 8	14	12
8 4	19	30	half	18	48
half	24	55	3 9	24	18
9 3	31	7	half	30	25
half	38	26	2 10	37	35
10 2	47	9	half	46	8
half	57	35	1 11	56	22
11 1	69	51	half	68	26
half	83	37	12	85	5

(Hour diſtances on the Plain.)

South De. 26d. 33' 54'' Re.	36d	0'	0''
The Ar. of the Pl. between the Mer. and the Hor.	72	0	0
The Ar. bet. Pl. and Ze.	31	43	2
The height of the Stile.	5	44	15
Deflection.	3	33	36
Plain's Difference of Longit.	31	53	40

Hours and halves from the Subſtile. *Subſtile*	00d	00m	*Hours and halves from the Subſtile.* *Subſtile*	00d	00m
10 2	00	11	half	00	34
half	00	57	9 3	01	20
11 1	01	44	half	2	09
half	02	36	8 4	3	03
12	03	34	half	4	06
half	04	41	7 5	05	21
1 11	06	06	half	06	56
half	07	57	6 6	09	07
2 10	10	36	half	12	26
half	14	53	5 7	18	13
3 9	23	15	half	31	09
half	45	32	4 8	71	41

(Hour Diſtances upon the Plain.)

CHAP. VI.

Of the Icoſaedron.

Figure V.

THE *Icoſaedron* is a Solid Body conſiſting of 20 Equal Sides, or Baſes, and 12 Solid Angles; each Baſe being an Equilateral Triangle.

I. *How to cut this Body in Wood or Stone.*

PRepare a Round Piece of Stone or Timber, and if you make the Diameter thereof to be 1.0000, let the length thereof be 0.8075, or in leſſer terms, if the Diameter be 4910, let the length be 3974. Then divide the ends of the Cylinder into 6 equal Parts, making the two ends, two Hexagons or figures of 6 equal ſides, drawing lines down the ſides, and Plaining away the Reſidue between Line and Line. Then making 5000 the former Semidiameter, now to be 1.000, take 616 of thoſe Parts, and on the two Centers at each end of the Piece, deſcribe two Circles, and by drawing Lines from each oppoſite Point of the ſix ſided figures, you ſhall have Points in the ſmaller Circle whereby to draw two Triangles for two Baſes or Plains of your Body, Equal and Parallel to each other.

Then making the length of the Piece to be 1.000, ſet .379 and .095 upon the edges of the Piece from each end, and by thoſe Points draw lines round the Piece, Laſtly, Diagonal lines being drawn round the Piece, from Point to Line; and from Line to Point; ſhall direct you how to cut the Body at 12 Cuts. And if you cut a Bevel or Templet to an Angle of 138 deg. 11 min. 23 ſec. You may examine the truth of your Body when it is thus Finiſhed.

The Figure of this Body as a Solid, as alſo how to deſcribe it upon Paſteboard, you have in Fig. V.

II. *Of the Dials which will furniſh this Body.*

THis Body conſiſting of 20 Plains, of which one being made the Foot or Baſe, its oppoſite Plain will be capable to receive an Horizontal Dial as the Plain D, and if you ſet any Angle thereof as that marked with ☿ to behold the South; then, the *Requiſites* and *Hour Diſtances* belonging to all the reſt of the *Plains*, will be ſuch as the ſeveral Tables following do exhibite.

I. *For*

I. *For the North Plain* G. *Reclining* 48 *deg.* 11 *min.* 23 *sec.*

North Re.	48*d*.	11′	23″
Stiles h.	86	39	23

Hours from the Meridian. — *Hour distances upon the Plain.*

12		00*d*	00′
half		7	29
1	11	14	59
half		22	28
2	10	29	57
half		37	27
3	9	44	57
half		52	27
4	8	59	57
half		67	28
5	7	74	59
half		82	29
6	6	90	00

South Re. E F	48*d*	11′	23″
Declining	60	00	00
The Arch of the Pl. between the Merid. and Hor.	37	45	41
The Arch of the M. between the Pl. and the Ze.	65	54	19
Stiles Height	22	06	03
Deflection	16	41	13
Diff. of Longit.	38	30	50

Hours from the Substile. — *Hour distances upon the Plain.*

half		00*d*	24
10	2	3	14
half		6	11
11	1	9	19
half		12	46
12		16	42
half		21	19
1	11	27	0
half		34	13
2	10	43	45
half		56	34
3	9	73	16
Substile		00	00
9	3	2	26
half		5	20
8	4	8	25
half		11	45
7	5	15	32
half		19	56
6	6	25	17
half		32	0
5	7	40	48
half		52	36
4	8	68	13
half		87	12

South Rec. H I.	19*d*	28′	16″
Declin.	22	14	29
Ark of the Plain between the Mer and Horizon.	82	14	19
Arch of the Mer. between the P. and Zenith.	20	54	18
Stiles Height	16	22	19
Deflection	6	26	34
Diff. of Longit.	21	49	56

Hours from the Substile. — *Hour Distances upon the Plain.*

11	1	1*d*	56*m*
half		4	07
12		6	27
half		9	00
1	11	11	55
half		15	24
2	10	19	44
half		25	26
3	9	33	22
half		45	09
4	8	63	01
half		87	38
Substile		00	00
half		0	11
10	2	2	19
half		4	32
9	3	6	53
half		9	29
8	4	12	30
half		16	06
7	5	20	37
half		26	38
6	6	35	8
half		47	49
5	7	66	58

North

North Re. K L.	19d	28'	16''
Declining E and W.	82	14	19
The Arch of the Pl. between the Merid. and Hor.	22	14	19
The Arch of the M. between the Pl. and the Ze.	69	05	41
Stiles Height	19	53	19
Deflection	71	17	00
Diff. of Longit.	83	25	34

Hours from the Substile.	*Hour distances upon the Plain.*	
half	00d	19
5 7	2	53
half	5	33
4 8	8	23
half	11	31
3 9	15	06
half	19	21
2 10	24	38
half	31	38
1 11	40	42
half	53	37
12	71	17
Substile	00	00
6 6	2	15
half	4	53
7 5	7	40
half	10	43
8 4	14	10
half	18	14
9 3	23	13
half	29	35
10 2	38	08
half	50	01
11 1	66	26
half	87	17

North Rec. M N.	19d	28'	16''
Declin.	19	28	16
Ark of the Plain between the Mer and Horizon.	75	31	11
Arch of the Mer. between the P. and Zenith.	24	50	41
Stiles Height	46	26	21
Deflection	48	02	04
Diff. of Longit.	56	54	32

Hours from the Substile.	*Hour Distances upon the Plain.*	
half	3d	12m
9 3	8	41
half	14	19
10 2	20	12
half	26	24
11 1	33	2
half	40	13
12	48	2
half	56	32
1 11	65	44
half	75	32
2 10	85	44
Substile	00	00
8 4	2	14
half	7	43
7 5	13	19
half	19	9
6 6	25	17
half	31	50
5 7	38	55
half	46	37
4 8	55	0
half	64	4
3 9	73	46
half	83	55

Thus have you all the Requisites and Hour Distances belonging to the Ten Superiour or Reclining Plains noted with E F G H I K L M N, the which will also serve for the Nine inferiour or Inclining Plains: By observing the directions given in *Tractate* I. *Chap.*

For	O, P, Q, R, S, T, V, W, X	The Recliner, shall be opposite to	E, F, G, H, I, K, L, M, N	Its Incliner

CHAP.

CHAP. VII.

Of a Regular Polyhedron, *called the* Canted Cube.

THIS Body conſiſts of which 26 Plains, of 16 are Geometrical Squares; and 8 are Equilateral Triangles, the ſides of both being equal.

I. *To Cut this Body in Wood or Stone:*

PRepare a *Parallellipipedon*, or Long Cube; and if you make the ſide of the Square at the End to be 9000, the length of the depth of the piece muſt be 7244: Then divide the ſides of the Squares at each end of the Piece into 3 equal Parts, ſo will each of them contain 3000 Parts, and from the ends of theſe lines, draw lines down the ſides of the Piece, Then take 2122 of thoſe Parts, and ſet them upon all the ſide lines from both ends, gageing lines round about the Piece; ſo ſhall you have lines to direct you to cut the Body at 8 Cuts: called,

Icoſahexaedron *or* Hexicoſaedron.

II. *Of the Dials proper for this Body.*

DEſigning the Square Plain for the Horizontal Dial, and ſetting any of the Angles thereof, as that marked with ♀, to behold the South, then will the four ſuperiour *Triangular Plains* B C D and E anſwer to the four Cardinal Points of the Horizon, namely to the *Eaſt*, *Weſt*, *North* and *South* Points, and all of them will Recline 35 deg. And the four inferiour *Triangular Plains* F G H and K will Incline as much, and ſo

<table>
<tr><td rowspan="4">The Plain</td><td>B</td><td rowspan="2">will be a direct</td><td>South</td><td rowspan="2">Dial Reclining 35 deg.</td></tr>
<tr><td>C</td><td>North</td></tr>
<tr><td>D</td><td rowspan="2">will be a direct</td><td>South</td><td rowspan="2">Dial Reclining 35 deg.</td></tr>
<tr><td>E</td><td>North</td></tr>
</table>

The four inferior Triangular Plains F G H K, will be Eaſt, Weſt, North and South Incliners 35 deg. and the Dials of the Recliners will ſerve for the Incliners.

The four Superiour Square Plains L M N and O, will be Recliners Declining; For each of them do Recline 45 deg. and Decline as much.

<table>
<tr><td rowspan="4">The Plain</td><td>M</td><td rowspan="4">will be a</td><td rowspan="2">South declining</td><td>Eaſt</td><td rowspan="4">45 degrees</td></tr>
<tr><td>N</td><td>Weſt</td></tr>
<tr><td>L</td><td rowspan="2">North declining</td><td>Eaſt</td></tr>
<tr><td>O</td><td>Weſt</td></tr>
</table>

 The

The Four inferiour Square Plains Y Z Æ J will be South-Eaſt, South-Weſt; North-Eaſt, and North-Weſt; Declining 45 deg. and Inclining 45 deg. alſo, and the Dials for the Superior or Recliners will ſerve for their oppoſite Incliners alſo:

The other Eight Square Plains P Q R S T V W X, are all Erect Plains, And of them,

The Plain	P Q R S	is an Erect Direct	South North E aſt Weſt	Plain

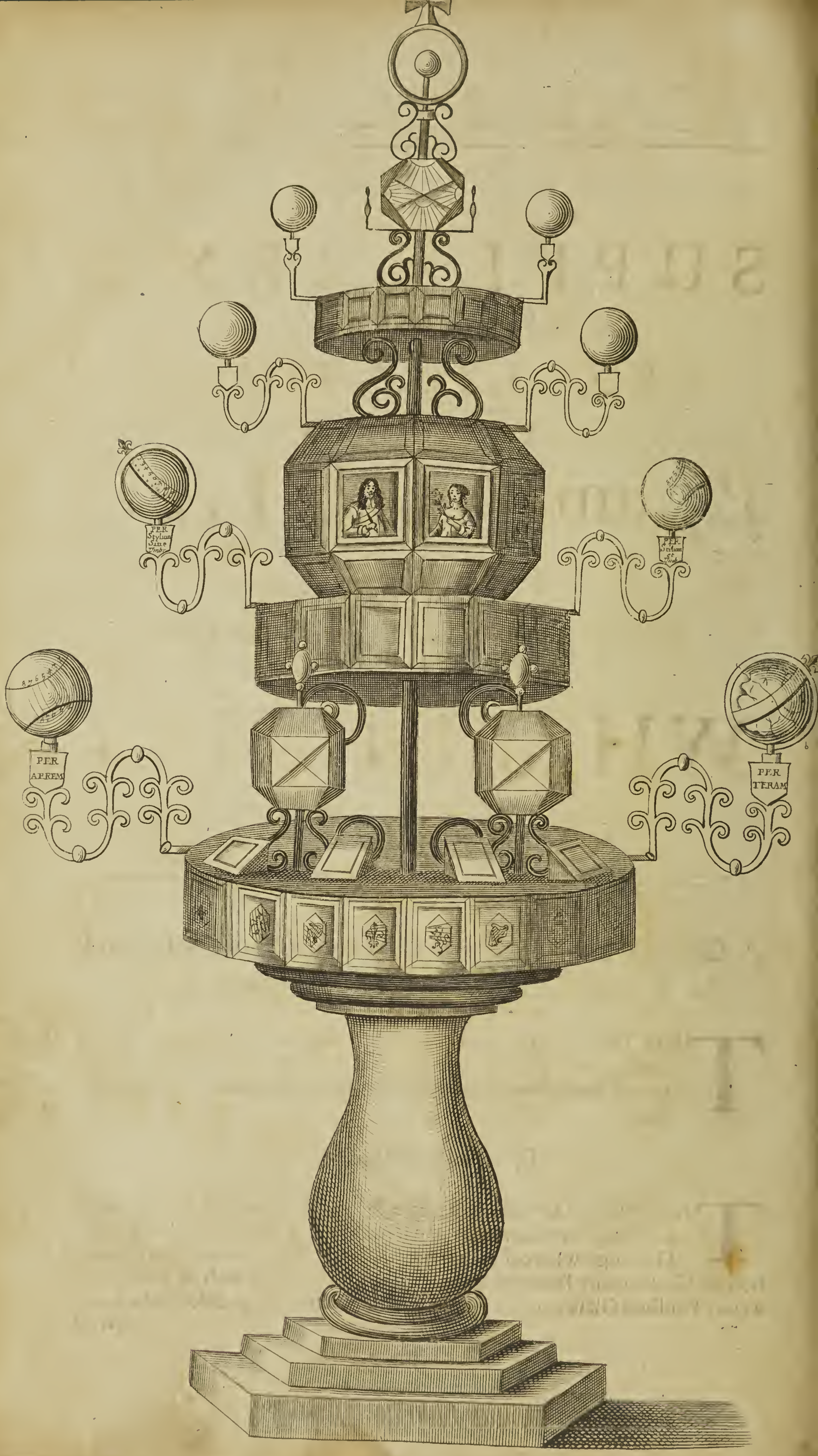
And

The Plain	T V W X	is an Erect Plain declining from the	South	Eaſtward Weſtward	45 degrees.
			North	Eaſtward Weſtward	

And thus have you 25 Dials upon one Body, beſides the Baſe, and in theſe you have Examples of all ſorts of Dials, viz.

Of	Erect Direct Erect Declining Direct Reclining, and Inclining Declining, Reclining and Inclining	Plains.

The End of the Fourteenth TRACTATE.


PER Stylum Sine
PER
PER ARREM
PER TERAM

A

SUPPLEMENT,

BEING A BRIEF

EXPLICATION

OF A

Pyramidical DIAL,

Which was ſet up in the

KING'S MAJESTY'S Privy Garden

AT

WHITE-HALL,

ANNO 1669.

A General Deſcription of the ſeveral Parts, of which the Pyramid (or Body) *was compoſed.*

THIS Dial ſtanding on a Pillar or Pedeſtal of Stone, conſiſts chiefly of Six Parts or Pieces, one leſs than another, and placed one above another in Form of a *Pyramis*, as in the Figure.

Of the Firſt Piece.

THE firſt and largeſt of theſe Six Pieces, is a Round Table of about 40 Inches in Diameter, and ſome 8 or 9 Inches in Thickneſs: The Edge whereof is cut into 20 equal Plains, which being made hollow like ſo many Boxes of an Inch deep, are covered each of them with a clear Poliſhed Glaſs; and on the in-ſide of each Glaſs is deſcribed a Dial; whereof

whereof some of them shew the Hour according to the Ancient or *Jews* manner of counting the Hours: Others according to the counting used by the *Babylonians*: Others according to the *Italians*: Others according to the way of counting used by *Astronomers*: And lastly others shew what Hour it is according to our usual and ordinary way of counting the Hour used in most parts of *Europe*. These 20 Dials thus described on the Edge of this Table or First Piece, are all Vertical Declining Dials; whose Stile or Gnomon is either a Lions Paw, or Unicorns Horn, or such like, relating to His Majesty's Arms, and painted on the bottom of the Box.

Moreover upon the upper Part of this Table, are placed Eight Reclining Dials, all made hollow, and covered with Polished Glass like the former, but differ chiefly in this; that they shew only the usual Hour in different ways: One of them shewing the Hour by the Shade of the Stile falling upon the Hour-Lines: Another by the Shade of the Hour-Lines falling upon the Stile: A Third without any Shade either of Hour-Lines or Stile, *&c.*

Upon this Piece stand also 4 Globes, cut into several Panes: Upon one of which Globes are described several Dials belonging to Geography: On another, Dials belonging to Astronomy: the Third Dials shewing several things appertaining to Astrology, as what Planet Reigns every Hour: The Horoscope, Aspect of the Sun with the Stars, *&c.*

There are also belonging to this Piece, and issuing out of the Sides thereof towards the East, West, North, and South, Four Iron Branches supporting each of them a Glass Boul which shew the Hour in Four different ways.

Of the Second Piece.

THE Second Piece of the Pyramis is also a Round Table, almost like the former, but somewhat less, having only 30 Inches in Diameter: It stands upon the First, held up by Four Iron Supporters. The Edge or Circumference of this Table is cut into 16 Equal Plains, all made hollow, and covered with Glass, like those of the First Table. But they differ from them in this, that here the Dials are not described on the Glass Covers, but on the bottom of the Boxes: Neither do they shew the Hour but the different Risings of the most remarkable Stars, according to the three manner of Risings observed by Astronomers, *Viz.* Cosmical, the Acronycal, and the Heliacal Rising. The Style to these Dials is a little Star painted upon the Inside of the Glass Cover, the better to keep it from the weather.

Out of the Sides of this Piece issue out Four Branches towards the East, West, North, and South, and carry on each of them a Glass Boul to shew the Hour, like those of the First Piece, but in a different way. For one of them shews the Hour by a Style without a Shadow, another shews it by a Shadow without a Style, *&c.* whereas those of the First Table shew it by the Four Elements, Fire, Air, Water, Earth.

On the upper part of this Table are placed Eight Reclining Planes, Four whereof are covered each of them with a Plate of Looking Glass, on which the Hour Lines, or Style of the Dial, being painted, are Reflected upon the bottom Inclining Plains, of the Third Piece, and there shew the Hour.

Other

Other Four have all Dials upon them, which are to be ſeen each of them in a Looking Glaſs placed upon the ſaid bottom Inclining Plains, of the Third Piece.

Of the Third Piece.

THE Third Piece of this Pyramidical Dial, is a great hollow Globe, of about 24 Inches in Diameter, and is placed immediately without any Supporter upon the ſecond Piece. The Superficies of this Globe is cut into 26 Plains, two whereof being *Octogons*, ſerve for top and bottom; the reſt are divided into 8 equal Reclining Plains, 8 equal Inclining Plains, and 8 equal Vertical or Upright Plains. Theſe Plains are all of them made hollow, like thoſe of the firſt and ſecond Piece. The Incliners are not covered with Glaſs, but left open, that they may the better receive and ſhew the Dials Reflected from the ſecond Piece.

Two of the 8 Upright Plains looking towards the North, have no bottoms, but are covered only with clear Glaſs, as ſerving only for Windows to look into the Globe, and behold there the Dials deſcribed on the Globe, which are ſeen as well without the ſame, as within. The other 6 have not only each of them a cover of clear poliſhed Glaſs, with a Dial deſcribed thereon, like thoſe of the firſt Piece, but have alſo a Glaſs for their bottom, which Glaſs is thinly painted over with White Colour, to the end the ſhade of the Hour Lines, drawn upon the Cover, may be ſeen as well within the Globe as without. On theſe bottom Glaſſes are drawn ſeveral Pictures, holding either a Scepter or a Truncheon, or the like, the end whereof points the Hour you look for.

Two alſo of the Recliners looking towards the North, have only a Glaſs Cover, ſerving for a Window to look into the Globe. The other 6 have a double Glaſs, like the former. Their Dials are ſome drawn upon the Cover, others upon the bottom, but all ſo contrived, that the Hour cannot be known by them, but only by looking within the Globe.

Moreover, From the top of this Globe iſſue 4 Iron Branches towards the four parts of the World, each of them carrying a Glaſs Bowl, proportionably leſs than thoſe of the firſt and ſecond Piece; on which Bowl are alſo Dials deſcribed, but different from the former, ſhewing the Hour according to the ſeveral ways of counting the Hours. Theſe Bowls are painted on the inſide with thick Colour, to keep out the Light, except a little place which is left clear, like a Star, for the Suns Beams, to paſs thorow and ſhew the Hour, and the place alſo where the Hour Lines are drawn, only painted on the outſide thinly with White Colour, that the light of the Sun paſſing thorow, the ſaid *Star* may be ſeen and ſhew the Hour.

Of the Fourth Piece.

THE Fourth Peice ſtanding on the aforeſaid Globe, and held up by the four Iron Supporters, like to thoſe which hold up the ſecond piece, but proportionably leſs, is alſo a Round Table of about 20 inches Diameter, and 6 in thickneſs. The edge of this Table is cut into 12 equal Superficies, not plain as heretofore, but concave like ſo many concave Semi-Cylinders; on each of which is deſcribed a Dial, which ſhews the uſual Hour by the ſhade of a *Flower de Luce*, fixed at the top of each Semi-Cylinder.

From the top of this Table iſſue forth four Iron Branches carrying each a Glaſs Bowl, juſt like thoſe of the Firſt, Second, and Third Piece, though proportionably leſs. The Dial deſcribed on theſe Glaſs Bowls, differ from thoſe of the Third Piece, not only becauſe they ſhew only the uſual Hour, but alſo becauſe here the Hour Lines are all left clear for the Suns Beams to paſs through; that by ſo paſſing they may exhibite the like Dial on the oppoſite ſide of the Bowl; which ſide is for that purpoſe thinly painted over with White Colour, that the ſaid Hours may be ſeen, and ſhew their Hour by their paſſing over a little Star, painted in the middle thereof.

Of the Fifth Piece.

THE Fifth Piece ſtanding upon the Fourth, and held up alſo by four Iron Supporters, is a Globe of about four Inches Diameter, whoſe Superficies is cut into Fifteen Plains, eight whereof are Triangles Equal and Equilaterial; the other ſix are Equal Squares. The Dials deſcribed on theſe Plains ſhew only the uſaul Hour, by the ſhade of a *Flower de Luce*, faſtned to the top or bottom of each Plain.

Of the laſt or higheſt Piece.

THis higheſt Piece or top of the Pyramid, is a Glaſs Bowl of ſome ſeven Inches Diameter, ſtanding upon a foot of Iron placed on the middle of the Fifth piece. The North ſide of this Bowl is thinly painted over with White Colour, that the ſhade of a little Golden Ball, that is placed in the middle of the Bowl, may be ſeen to paſs over the Hour Lines, which are drawn upon the ſaid White Colour, and note the Hour. The Bowl is included between two Circles of Iron guilded, with a croſs on the top. And thus much concerning this *Pyramidical Dial* in general.

I. *Of the Twenty* Vertical Dials *described on the first Piece.*

Four of those Dials have a		Painted in the bottom of the Box, and shew the		Hour by the shadow of the Lines drawn upon the Glass passing over the	
	Lion		*Jewish*		*Paw of the Lion.*
	Harp with a Scepter		*Babylonish*		*Top of the Scepter.*
	Flower de Luce		*Italian*		*Top of the Flower de Luce.*
	Unicorn		*Astronomical*		*Unicorns Horn.*
	Lion also		*Common*		*Lions Paw.*

II. *Of the Eight* Reclining Dials, *standing upon the First Piece.*

These four Recliners *which stand upon the South part,*

The		Shews the hour	
	First		*By the Stile passing over the Hour Lines.*
	Second		*Both by the Shadow of the Hour Lines passing over the Stile.*
	Third		*By the shadow of the Stile passing over the Hour Line, and the Hour Lines over the Stile.*
	Fourth		*Without shade either of Stile or Hours.*

Those four Recliners *standing on the North part,*

In the		
	First	*You see the Hour Lines, but no Stile.*
	Second	*You see the Stile but no Hour Lines.*
	Third	*You see neither Stile nor Hour Lines.*
	Fourth	*You see both Hours and Stile.*

III. *Of the four* Glass Bowls *which stand upon the First Piece.*

These four Bowls shew the common Hours by four different ways : viz.

The		by		
	First		*Fire*	*By applying your Finger to the Meridians.*
	Second		*Water*	*By the Rays of the Sun passing through the Water.*
	Third		*Air*	*By two Objects made in the Globe, and reposing your Eye.*
	Fourth		*Earth*	*By a Terrestial Globe described upon the Bowl.*

IV. *Of*

IV. *Of the four great* Globes *standing on the First Piece.*

EAch Globe consisteth of 32 Plains, of which 20 are Equilateral Triangles, and 12 Regular Pentagons; the Triangles are all Plains, and some of the Pentagons also, and the Stiles of these Dials are a sharp pointed Iron, perpendicularly erected.

Of these Dials described on the First Globe,

Some shew in what part of the World
It is time of Rising or 6 a Clock,
It is time of Dining or Mid-day.
It is Supper time or 6 a Clock.
It is Mid-night or 12 a Clock.
The Sun is in the Zenith.

The Dials upon the 20 Triangles shew what a Clock it is in divers other Countrys in the World.

Of the Dials drawn upon the Second Globe, shew

Some of them
The Azimuth or distance of the Sun from the South.
The Almicanter or degrees of Altitude.
The Suns Rising.
The Suns Setting.
The Amplitude or distance of rising from the East or West.
The Day of the Month, &c.

Of the Dials described upon the Third Globe.

This Globe consisteth of 20 Equilateral Triangles, some whereof are made hollow like Cones, the rest left Plain.

The Dials shew by the shadow of the Stile *What Constellation.*
Begins to Rise.
Begins to Set.
Begins to pass the Meridian.
Is just East or West.
Is in our Zenith.
Will be just East or West at 8 at Night.
Will be just South at 8 at Night.

Of

Of the Dials upon the Fourth Globe.

This Globe (as the former) consists of 20 Equilateral Triangles; and the Dials described upon them,

Shew by the Shadow of the Stile
- *What Sine is ascending.*
- *What Sine is culminating.*
- *What Sine is descending.*
- *In which of the 12 Houses the Sun is.*
- *What Planet Reigneth any day of the Week.*
- *What fixed Stars are in Conjunction with the Sun.*
- *What Aspect the Sun hath to fixed Stars.*

V. *Of the Dials on the edge of the Second Piece.*

The *Dials* described upon the edge of this Second Piece,

Shew the { *Cosmical* / *Achronical* / *Heliacal* } *Rising and Setting of the fixed Stars.*

VI. *Of the* 8 Reflected Dials, *placed on the top of the second* Table.

THE Dials made upon the top of this second *Table*, being high and above the Eye, are made by Reflection; for the Dials drawn upon the Inclining Plain, the Stile being a *Flower de Luce*, painted upon the Looking-glass, placed on the Table, appears not, but only the shadow thereof appears, which being Reflected upon the Hour Lines, drawn on the bottom of the Globe, shews the Hour.

VII. *Of the Four* Dials *supported by the Four Branches Of the Second Piece.*

THese four Dials are drawn upon four Glass Globes, of about five inches Diameter, and shew the usual Hour for several ways.

The First shews the Hour by moving the Stile (which here is a *Flower de Luce* fixed on a moveable Equator) to and fro till it cast no shadow upon the Globe; so shall the Equator rest upon the Hour.

The Second shews the Hour, by observing where the part of the Globe, enlightned by the Sun, meets with the part not enlightned, for that will be at the true Hour.

The Third shews the Hour, by the shadow of a Stile perpendicularly erected upon the Superficies of the Globe.

The Fourth ſhews the Hour by placing of your Body ſo as to behold your Face in the middle of a little Convex Looking-glaſs placed for that purpoſe in the South Pole of the Bowl or Globe; you ſhall at the ſame time (if the Sun ſhine) behold the Picture thereof at the Hour.

VIII. *Of the* Dials *deſcribed on the great* Globe, *which ſtands on the Second* Table.

THis Globe conſiſts of 24 Plains, 8 Recliners, 8 Vertical, and 8 Inclining Plains: For the Dials upon them, ſix of the upright Plains are made hollow and covered with Glaſs, having Dials drawn upon them: The bottoms here alſo are covered with Glaſs thinly painted over with White Colour, that the Dials may be ſeen as well within as without the Globe; the two Hollows towards the North being left open as Windows to look into the Globe. On the bottom Glaſſes are drawn ſeveral Pictures, as of the King, Queen, *&c.* In the King's Picture the Hour is ſhewed by the Hour Lines Paſſing over the top of the Scepter. In the Queen's, by the Shadow paſſing over the Center of a Flower in her Hand; and the reſt over ſeveral Truncheons, *&c.* held in their Hands.

For the Dials deſcribed upon the Reclining and Inclining Plains; they are of the like kind (by Reflection) as thoſe before deſcribed in the former Globe.

IX. *Of the Four* Glaſs Bowls, *ſupported by the Four Branches of the great* Globe.

THeſe four Bowls are gilded over, except where the Hour Lines are drawn, which is thinly painted over with White Colour, to the end, the Sun Beams paſſing through a little Star, left clear on the top of the Bowl, and making the like Star of Light upon the Hour Lines, may be ſeen to note the Hour. The Hours were ſuch as ſhew the Hour according to different Nations.

X. *Of the uppermoſt Piece of the* Pyramis.

THis Fourth and uppermoſt Piece, conſiſting of 12 Concave Semi-Cylinders, and ſtanding upon the Great Globe, held up by four Supporters, like thoſe which held up the ſecond Piece. Upon each of thoſe Semi-Cylinders is a Dial deſcribed, ſhewing the uſual Hour by the light of the Sun penetrating through the Hour Lines, and paſſing over a little Star, painted on the lower part of the Bowl.

The

The Fifth Piece consisting of eight plain Equilateral Triangles and six equal Squares, and held up by four Supporters, have Dials described upon them, shewing the Hour by the shade of a *Flower de Luce.*

The Sixth and last Piece is a great Glass Bowl, standing upon the Fifth, supported by a foot of Iron, and encompassed with two Iron Circles. Which Bowl also shews the Hour by the shade of a little Golden Ball placed in the middle of the Glass.

Thus have I given a brief Account of this (now demolished) Dial which Account and Figure thereof together, may give some light to the ingenious Practicioner (with what is delivered in the foregoing Tractates) to invent infinite Varieties in this kind.

FINIS.

Wt of Thos Fenwicks
Pigg Hd ft and Luggs
is — — 12 - 7 - — 2 .. 10